METHODS AND COMPOSITIONS FOR TREATING POLYCYSTIC OVARY SYNDROME

Related Applications

This application is a continuation-in-part of U.S. Application No. 10/317,126 filed December 11, 2002, and is a continuation-in-part of International Application No. PCT/US03/01109, which is a continuation of U.S. Application No. 10/317,126 filed December 11, 2002 and claims priority to U.S. Provisional Application No. 60/350,395 filed January 22, 2002.

Field of the Invention

The present invention relates to endocrinology and pharmacology. More particularly, it relates to methods and compositions for treating subjects suffering from polycystic ovary syndrome (PCOS).

Background of the Invention

Polycystic ovary syndrome (PCOS), also known as polycystic ovarian disease or Stein-Leventhal syndrome, affects an estimated 6-10% of women in the United States. PCOS is characterized by anovulation (irregular or absent menstrual periods) and hyperandrogenism (elevated serum testosterone and androstenedione). Additional etiological and clinical symptoms of this disease can include abnormal uterine bleeding, enlarged multifollicular ovaries, infertility, obesity, insulin resistance, hyperinsulinemia, hypertension, hyperlipidemia, type-2 diabetes mellitus, excess facial hair growth, hair loss and acne.

Insulin resistance and hyperinsulinemia are highly prevalent in patients with PCOS and are thought to underlie the pathophysiology of this disease (Udoff, L., et al., *Curr. Opin. Obstret. Gynecol.* 7:340-343 (1995); Barbieri, R.L., *Am. J. Obstet. Gynecol.* 183:1412-8 (2000); Kim, L.H. et al., *Fertility and Sterility* 73:1097-1098 (2000); Iuorno, M.J. et al., *Obstet. Gynecol. Clin. North Am.* 28:153-164 (2001); Zacur, H.Z., *Obstet. Gynecol. Clin. North Am.* 28:21-33 (2001)). Recent studies suggest that the hyperandrogenism associated with PCOS is caused by an increase in ovarian androgen production (e.g., testosterone and androstenedione) and a decrease in serum androgen-binding globulin concentration, due to hyperinsulinemia. Insulin has been shown to directly stimulate production of androgens by the ovary, at least in part by increasing the activity

of P450c17α, an enzyme involved in the production of testosterone in the ovarian theca cells (Iuorno, M.J. et al., *supra*). At the level of the pituitary axis, hyperandrogenism suppresses follicle stimulating hormone (FSH) secretion, alters gonadotropin-releasing hormone (GnRH) release and increases lutenizing hormone (LH) secretion. These abnormalities, along with the local effects of androgens on the ovaries, lead to follicular involution, anovulation, and infertility. Similarly, oligomenorrhea and amenorrhea occur and are interspersed with heavy vaginal bleeding. Hyperinsulinemia may also lead to high blood pressure and increased clot formation and has been implicated in the development of cardiovascular disease, stroke and type-2 diabetes (Iuorno, M.J. et al., *supra*; Zacur, H.A., *supra*).

Traditionally, treatment of PCOS was directed primarily at correcting the underlying symptoms. For example, hirsutism and menstrual irregularities were treated with anti-androgenic drugs, including birth control pills, spironolactone, flutamide or finasteride. Infertility treatments have included weight loss diets, ovulation medications (e.g., clomiphene, follistim and Gonal-F), so-called "ovarian drilling" surgery, and *in vitro* fertilization. More recent treatments for PCOS are targeted towards lowering insulin levels. Insulin-sensitizing agents such as metformin, D-Chiro-inositol, diazoxide, and PPAR-gamma inhibitors (*e.g.*, troglitazone (Rezulin), rosiglitazone (Avandia) and pioglitazone (Actos)), have been demonstrated to restore fertility and reverse the endocrine abnormalities associated with PCOS. Although metformin and PPAR-gamma inhibitors do not interfere with pregnancy, they are generally discontinued during pregnancy because of concern over their safety and effect(s) on the fetus. Moreover, women with PCOS who become pregnant experience spontaneous abortion during the first trimester at rates as high as 30% to 50% (Iuorno, M.J. et al., *supra*; Zacur, H.A., *supra*; Phipps, W.R., *Obstet. Gynecol. Clin. North Am.* 28:165-182 (2001). Thus, there is a need for new and better compositions and methods for treating PCOS.

Summary of the Invention

Applicants have solved the above problem by discovering that glucagon-like peptide-1 (GLP-1), exendin, and agonists and analogs of these compounds are capable of lowering insulin resistance or increasing insulin sensitivity. The present invention relates to methods for treating PCOS using GLP-1, GLP-1 agonists, exendin, or exendin agonists. In one embodiment, the methods of this invention comprise administering to a patient a therapeutically effective amount of GLP-1, GLP-1 agonists, exendin, or exendin agonists. In another embodiment, the method

comprises reducing or preventing insulin resistance in a subject suffering from PCOS. In yet another embodiment, the method comprises preventing the onset of type-2 diabetes in a subject suffering from PCOS. In a further embodiment, the method comprises restoring regular menses, ovulation, or fertility in a subject suffering from PCOS.

In a preferred embodiment, the GLP-1 agonist is a GLP-1 analog with agonist activity, and the exendin agonist is an exendin analog with agonist activity. In another preferred embodiment, the subject is human.

By GLP-1 agonist is meant a compound that mimics the effects of GLP- 1 on PCOS by binding to the receptor or receptors where GLP- 1 causes this effect. Certain GLP-1 analogs with agonist activity are described in Chen *et al.*, U.S. Patent No. 5,512,549, issued April 30, 1996, entitled Glucagon-Like Insulinotropic Peptide Analogs, Compositions and Methods of Use. Other GLP- 1 analogs with agonist activity are described in Johnson *et al.*, U.S. Patent No. 5,574,008, issued November 12, 1996, entitled, Biologically Active Fragments of Glucagon-Like Insulinotropic Peptide. Still other GLP-1 analogs with agonist activity are described in Buckley *et al.*, U.S. Patent No. 5,545,618, issued August 13, 1996, entitled GLP-1 Analogs Useful for Diabetes Treatment. All three referenced U.S. patents are incorporated herein by this reference.

By an exendin agonist is meant a compound that mimics the effects of exendin on PCOS by binding to the receptor or receptors where exendin causes this effect. Certain exendin analogs having agonist activity are described in U.S. Provisional Patent Application Serial No. 60/055,404, filed August 8, 1997, which enjoys common ownership with the present invention and is hereby incorporated by this reference. Certain other exendin analogs with agonist activity are described in U.S. Provisional Patent 2 5 Application Serial Nos. 60/066,029 and 60/065,442, both filed November 14, 1997 which enjoy common ownership with the present invention and are hereby incorporated by this reference. Preferred exendin analogs having agonist activity include those described in U.S. Provisional Patent Application Serial Nos. 60/055,404 and 60/065,442.

Detailed Description of the Invention

Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. In case of conflict, the present application, including the definitions, will control. All publications, patents and other references mentioned herein are incorporated by reference.

Although methods and materials similar or equivalent to those described herein can be used in the practice of the present invention, suitable methods and materials are described below. The materials, methods, and examples are for illustrative purposes only, and are not intended to be limiting. Other features and advantages of the invention will be apparent from the detailed description and from the claims.

In order to further define the invention, the following terms and definitions are herein provided.

The term "alopecia" as used herein, refers to a condition in which a patient experiences loss of hair due to, *e.g.*, infections of the scalp or skin, nervousness, or a specific disease such as PCOS. The hair may fall out in patches or there may be diffuse loss of hair instead of complete baldness in one area.

The term "exendin" refers to naturally occurring exendin peptides that are found in the salivary secretions of the Gila-monster. Preferred exendins include exendin-3 [SEQ. ID. NO. 7], which is present in the salivary secretions of Heloderma harridum, and exendin-4 [SEQ. ID. NO. 9], which is a peptide present in the salivary secretions of Heloderma suspectum (Eng, J., *et al.*, *J. Biol. Chem.*, 265:20259-62, 1990; Eng., J., *et al.*, *J. Biol. Chem.*, 267:7402-05, 1992). Exendin-4, as it occurs in the salivary secretions of the Gila monster, is an amidated peptide. However, it should be understood that the term "exendin," "exendin-3," and "exendin-4" refer to both the amidated form of the peptide and the acid form of the peptide.

Exendin-4 was first thought to be a (potentially toxic) component of the venom. It now appears that exendin-4 is devoid of toxicity, and that it instead is made in salivary glands in the Gila monster. The exendins have some sequence similarity to several members of the glucagon-like peptide family, with the highest homology, 53%, being to GLP-1[7-36]NH2 (Goke, *et al.*, *J. Biol. Chem.*, 268:19650-55, 1993). "Exendin agonist" refers to compounds that mimic the effect of an exendin by binding to the receptor or receptors where the exendin causes this effect. Exendin "agonist activity" in this context means having the biological activity of an exendin, but it is understood that the activity of the analog can be either less potent or more potent than the native exendin. Other exendin agonists include, e.g., chemical compounds specifically designed to active that receptor or receptors at which an exendin exerts its affect on PCOS.

The terms "GLP-1," and "glucagon-like peptide-1," according to this invention both refer to GLP-1 amide [SEQ. ID. NO. 4], as well as the acid form of GLP-1, which is also known as

proglucagon[78-107]. "GLP-1 agonist" refers to compounds that mimic the effects of GLP-1 on PCOS by binding to the receptor or receptors where GLP-1 causes this effect. Preferred GLP-1 agonists are GLP-1 analogs with agonist activity. GLP-1 "agonist activity" in this context means having the biological activity of GLP-1 (7-36) amide (GLP-1(7-36)NH_2), but it is understood that the activity of the analog can be either less potent or more potent than native GLP-1(7-36) amide. Other GLP-1 agonists include, *e.g.*, chemical compounds specifically designed to activate the receptor or receptors at which GLP-1 exerts its affect on PCOS.

The term "hirsutism" as used herein, refers to a condition in which a patient exhibits abnormal hairiness.

The term "hyperandrogenism" as used herein, refers to a condition in which a patient exhibits elevated levels of androgens (*e.g.*, testosterone, androstenedione) in serum.

The term "hyperinsulinemia" as used herein, refers to a condition in which a patient exhibits elevated plasma insulin levels.

The term "hyperlipidemia" as used herein, refers to a condition in which a patient exhibits elevated concentrations of any or all lipids in plasma.

The term "hypertension" as used herein, refers to a condition in which a patient experiences persistently high blood pressure (*i.e.*, a systolic pressure equal or greater than 140 mm Hg and a diastolic pressure equal to or greater than 90 mm Hg).

The term "insulinotropic" as used herein, refers to an ability to stimulate the release of insulin into the circulation.

The term "insulin resistance" as used herein, describes a subnormal biological response to a given concentration of insulin (*i.e.*, decreased glucose transport across the cell membrane in response to insulin).

The term "pharmaceutically acceptable carrier or adjuvant" as used herein, refers to a non-toxic carrier or adjuvant that may be administered to a patient together with a compound of the invention, and which does not destroy the pharmacological activity thereof.

The terms "polycystic ovarian syndrome," "PCOS," "polycystic ovarian disease" or "Stein-Leventhal syndrome," as used herein refer to a disease affecting women. Women diagnosed with PCOS may exhibit one or more of the following symptoms: anovulation (irregular or absent menstrual periods), hyperandrogenism (elevated serum testosterone and/or androstenedione), abnormal uterine bleeding, enlarged multifollicular ovaries, infertility, obesity,

insulin resistance, hyperinsulinemia, hypertension, hyperlipidemia, type-2 diabetes mellitus, excess facial hair growth, hair loss, and acne.

The terms "therapeutically or pharmaceutically effective" or "therapeutically or pharmaceutically effective amount" refers to an amount of the compound of this invention required to reduce or lessen the severity of PCOS or any of its symptoms (*e.g.*, of insulin resistance, hyperinsulinemia, type-2 diabetes mellitus, obesity, hypertension, hyperlipidemia, anovulation or irregular ovulation, infertility, hyperandrogenism, hirsutism, alopecia, acne, enlarged multifollicular ovaries and abnormal uterine bleeding, for some period of time). A therapeutically or pharmaceutically effective amount also means the amount required to improve the clinical symptoms of a patient.

The term "type-2 diabetes mellitus" as used herein, refers to a disease, also known as non-insulin-dependent diabetes mellitus (NIDDM) or adult-onset diabetes mellitus (AODM), in which a patient has elevated concentrations of blood sugar levels.

The present invention relates to methods for treating PCOS in a patient. The methods include administering to a subject a therapeutically effective amount of GLP-1, exendin, and agonists and analogs of these compounds. The methods of this invention further relate to lowering insulin resistance using GLP-1, exendin, and agonists and analogs of these compounds. Many of the symptoms associated with PCOS stem from an underlying insulin resistance.

Glucagon-Like Peptide-1 (GLP-1)

GLP-1 plays a key role in the regulation of plasma glucose homeostasis. It is involved in stimulating insulin secretion and inhibiting glucagon release by the pancreas, inhibiting gastric acid secretion and motility, and suppressing appetite and food intake. GLP-1 is a member of the incretin group of secretagogue hormones that are released from intestinal enteroendocrine cells in response to the ingestion of food. GLP-1 binds to the GLP-1 receptor, which is expressed on the β-cells of the pancreas. Binding of GLP-1 to its receptor triggers an intracellular signaling pathway that results in stimulation of insulin secretion with concomitant inhibition of glucagon production. This in turn leads to inhibition of hepatic glucose production, which lowers blood glucose levels. Although the role of GLP-1 in maintaining plasma glucose concentration is well established, prior to this invention, it was not known that GLP-1 is also capable of increasing insulin sensitivity.

Mammalian GLP peptides and glucagon are encoded by the same gene. In the ileum, the precursor is processed into two major classes of GLP peptide hormones, namely GLP-1 and GLP-2. GLP-1(1-37) has the sequence: His-Asp-Glu-Phe-Glu-Arg-His-Ala-Glu-Gly-Thr-Phe-Thr-Ser-Asp-Val-Ser-Ser-Tyr-Leu-Glu-Gly-Gln-Ala-Ala-Lys-Glu-Phe-Ile-Ala-Trp-Leu-Val-Lys-Gly-Arg-Gly [SEQ ID NO: 1]. GLP-1(1-37) is amidated post-translationally to yield GLP-1(1-36)NH_2, which has the sequence: His-Asp-Glu-Phe-Glu-Arg-His-Ala-Glu-Gly-Thr-Phe-Thr-Ser-Asp-Val-Ser-Ser-Tyr-Leu-Glu-Gly-Gln-Ala-Ala-Lys-Glu-Phe-Ile-Ala-Trp-Leu-Val-Lys-Gly-Arg(NH_2) [SEQ ID NO: 2], or is enzymatically processed to yield GLP-1(7-37), which has the sequence: His-Ala-Glu-Gly-Thr-Phe-Thr-Ser-Asp-Val-Ser-Ser-Tyr-Leu-Glu-Gly-Gln-Ala-Ala-Lys-Glu-Phe-Ile-Ala-Trp-Leu-Val-Lys-Gly-Arg-Gly [SEQ ID NO: 3]. GLP-1(7-37) can also be amidated to yield GLP-1(7-36)amide, which has the sequence: His-Ala-Glu-Gly-Thr-Phe-Thr-Ser-Asp-Val-Ser-Ser-Tyr-Leu-Glu-Gly-Gln-Ala-Ala-Lys-Glu-Phe-Ile-Ala-Trp-Leu-Val-Lys-Gly-Arg(NH_2) [SEQ ID NO: 4]. Likewise, GLP-1(1-36)amide can be processed to GLP-1(7-36)amide.

Intestinal L cells secrete GLP-1(7-37) and GLP-1(7-36)NH_2 in a ratio of about 1:5. These truncated forms of GLP-1 have short half-lives *in vivo* (less than 10 minutes), and are inactivated by an aminodipeptidase (DPP IV) to yield GLP-1(9-37), which has the sequence: Glu-Gly-Thr-Phe-Thr-Ser-Asp-Val-Ser-Ser-Tyr-Leu-Glu-Gly-Gln-Ala-Ala-Lys-Glu-Phe-Ile-Ala-Trp-Leu-Val-Lys-Gly-Arg-Gly [SEQ ID NO: 5], and GLP-1(9-36)amide, which has the sequence: Glu-Gly-Thr-Phe-Thr-Ser-Asp-Val-Ser-Ser-Tyr-Leu-Glu-Gly-Gln-Ala-Ala-Lys-Glu-Phe-Ile-Ala-Trp-Leu-Val-Lys-Gly-Arg(NH_2) [SEQ ID NO: 6], respectively. It has been speculated that the peptides GLP-1(9-37) and GLP-1(9-36)amide might affect hepatic glucose production, but apparently they do not stimulate production or release of insulin from the pancreas.

As used in this specification, the term "GLP-1 analog" includes GLP-1(1-37), GLP-1(1-36)NH_2, GLP-1(7-37), GLP-1(9-37), GLP-1(9-36)NH_2 ("GLP-1(9-36)amide"). The present invention includes the use of recombinant human GLP-1 analogs and GLP-1 analogs derived from other species, whether recombinant or synthetic.

As used in this specification, the term "GLP-1 agonist" includes any molecules, whether they be peptides, peptide mimetics, or other chemical compounds, that bind to or activate a GLP-1 receptor or receptors at which GLP-1 exerts its affect on PCOS, such as the GLP-1(7-36)amide

receptor, and its second messenger cascade. For example, GLP-1 agonists include molecules having insulinotropic activity and that are agonists of (*i.e.*, activate) the GLP-1 receptor molecule and its second messenger activity on, *inter alia*, insulin producing β-cells.

"GLP-1 analogs" also include peptides that are encoded by polynucleotides that express biologically active GLP-1 analogs with agonist activity, as defined herein. For instance, GLP-1 analogs may be peptides containing one or more amino acid substitutions, additions or deletions, compared with GLP-1(7-36)amide. In one embodiment, the number of substitutions, deletions, or additions is 30 amino acids or less, 25 amino acids or less, 20 amino acids or less, 15 amino acids or less, 10 amino acids or less, 5 amino acids or less or any integer in between these amounts. In one aspect of the invention, the substitutions include one or more conservative substitutions. A "conservative" substitution denotes the replacement of an amino acid residue by another, biologically active similar residue. Examples of conservative substitutions include the substitution of one hydrophobic residue, such as isoleucine, valine, leucine, or methionine for another, or the substitution of one polar residue for another, such as the substitution of arginine for lysine, glutamic for aspartic acids, or glutamine for asparagine, and the like. The following table lists illustrative, but non-limiting, conservative amino acid substitutions.

ORIGINAL RESIDUE	EXEMPLARY SUBSTITUTIONS
ALA	SER, THR
ARG	LYS
ASN	HIS, SER
ASP	GLU, ASN
CYS	SER
GLN	ASN, HIS
GLU	ASP, GLU
GLY	ALA, SER
HIS	ASN, GLN
ILE	LEU, VAL, THR
LEU	ILE, VAL
LYS	ARG, GLN, GLU, THR
MET	LEU, ILE, VAL
PHE	LEU, TYR
SER	THR, ALA, ASN
THR	SER, ALA
TRP	ARG, SER
TYR	PHE
VAL	ILE, LEU, ALA
PRO	ALA

It is further understood that GLP-1 analogs include the above described peptides which have been chemically derivatized or altered, for example, peptides with non-natural amino acid residues (*e.g.*, taurine, β- and γ-amino acid residues and D-amino acid residues), C-terminal functional group modifications, such as amides, esters, and C-terminal ketone modifications and N-terminal functional group modifications, such as acylated amines, Schiff bases, or cyclization, as found, for example, in the amino acid pyroglutamic acid.

Also included in the present invention are peptide sequences having greater than 50% sequence identity, and preferably greater than 90% sequence identity to (1) SEQ ID NOS: 1, 2, 3, and 4; and (2) to truncated sequences thereof. As used herein, sequence identity refers to a comparison made between two molecules using standard algorithms well known in the art. The preferred algorithm for calculating sequence identity for the present invention is the Smith-Waterman algorithm, where SEQ ID NO: 1 [*i.e.*, GLP-1(1-37)] is used as the reference sequence to define the percentage identity of homologs over its length. The choice of parameter values for matches, mismatches, and insertions or deletions is arbitrary, although some parameter values have been found to yield more biologically realistic results than others. One preferred set of parameter values for the Smith-Waterman algorithm is set forth in the "maximum similarity segments" approach, which uses values of 1 for a matched residue and -⅓ for a mismatched residue (a residue being either a single nucleotide or single amino acid). Waterman, *Bull. Math. Biol.* 46; 473 (1984). Insertions and deletions (indels), x, are weighted as $x_k = 1 + ⅓k$, where k is the number of residues in a given insert or deletion. *Id.*

For instance, a sequence that is identical to the 37-amino acid residue sequence of SEQ ID NO: 1, except for 18 amino acid substitutions and an insertion of 3 amino acids, would have a percent identity given by:

[(1 × 37 matches) - (⅓ × 18 mismatches)
- (1 + 3/3 indels)] / 37 = 78% "identity"

Agonists of glucagon-like peptide that exhibit activity through the GLP-1(7-36)amide receptor have been described. *See* EP 0708179 A2; Hjorth *et al.*, *J. Biol. Chem.* 269; 30121 (1994); Siegel *et al.*, Amer. Diabetes Assoc. 57th Scientific Session, Boston (1997); Hareter *et al.*, Amer. Diabetes Assoc. 57th Scientific Session, Boston (1997); Adelhorst *et al.*, *J. Biol. Chem.* 269, 6275 (1994); Deacon *et al.*, 16th International Diabetes Federation Congress

Abstracts, *Diabetologia Supplement* (1997); Irwin *et al.*, *Proc. Natl. Acad. Sci. USA* 94; 7915 (1997); Mojsov, *Int. J. Peptide Protein Res.* 40; 333 (1992). Göke & Byrne, *Diabetic Medicine* 13; 854 (1996). Recent publications disclose Black Widow GLP-1 and Ser^2 GLP-1. *See* Holz & Hakner, *Comp. Biochem. Physiol.,* Part B 121; 177 (1998) and Ritzel *et al.*, *J. Endocrinol* 159; 93 (1998).

GLP-1 receptors are cell-surface proteins found, for example, on insulin-producing pancreatic β-cells; the GLP-1(7-36) receptor has been characterised in the art. Methods of determining whether a chemical or peptide binds to or activates a GLP-1 receptor are known to the skilled artisan.

The biological activity of a GLP-1 agonist can be determined by *in vitro* and *in vivo* animal models and human studies, as is well known to the skilled artisan. GLP-1 biological activity can be determined by standard methods, in general, by receptor binding activity screening procedures, which involve providing appropriate cells that express the GLP-1 receptor on their surface, for example, insulinoma cell lines such as RINmSF cells or INS-1 cells. *See* Mojsov, *Int. J. Peptide Protein Res.* 40; 333 (1992) and EP 0708179 A2. Cells that are engineered to express a GLP-1 receptor also can be used. In addition to measuring specific binding of tracer to membrane using radioimmunoassay methods, cAMP activity or glucose dependent insulin production can also be measured. In one method, a polynucleotide encoding the GLP-1 receptor is employed to transfect cells so that they express the GLP-1 receptor protein. Thus, for example, these methods may be employed for screening for a receptor agonist by contacting such cells with compounds to be screened and determining whether such compounds generate a signal (*i.e.*, activate the receptor). Other screening techniques include the use of cells that express the GLP-1 receptor, for example, transfected CHO cells, in a system to measure extracellular pH or ionic changes caused by receptor activation. For example, potential agonists may be contacted with a cell that expresses the GLP-1 protein receptor and a second messenger response (*e.g.*, signal transduction or ionic or pH changes), may be measured to determine whether the potential agonist is effective.

Polyclonal and monoclonal antibodies can be utilized to detect, purify, and identify GLP-1-like peptides for use in the methods described herein. Antibodies such as ABGA1178 detect intact GLP-1(1-37) or N-terminally-truncated GLP-1(7-37) or GLP-1(7-36)amide. Other antibodies detect the end of the C-terminus of the precursor molecule, a procedure that allows

one—by subtraction—to calculate the amount of biologically active, truncated peptide (*i.e.*, GLP-1(7-37)amide). Orskov *et al.*, *Diabetes* 42; 658 (1993); Orskov *et al.*, *J. Clin. Invest.* 1991, 87; 415 (1991).

GLP-1 and the GLP-1 agonists of the invention that are peptides that can be made by solid-state chemical peptide synthesis. Such peptides can also be made by conventional recombinant techniques using standard procedures described in, for example, Sambrook & Maniatis, Molecular Cloning, A Laboratory Manual. "Recombinant," as used herein, means that a gene is derived from a recombinant (*e.g.*, microbial or mammalian) expression system that has been genetically modified to contain a polynucleotide encoding a GLP-1 peptide as described herein.

GLP-1 and the GLP-1 agonists of the invention that are peptides may be a naturally purified product, or a product of synthetic chemical procedures, or produced by recombinant techniques from prokaryotic or eukaryotic hosts (for example, by bacteria, yeast, higher plant, insect, or mammalian cells in culture or *in vivo*). Depending on the host employed in a recombinant production procedure, the polypeptides of the present invention are generally non-glycosylated, but may be glycosylated. The GLP-1 peptides can be recovered and purified from recombinant cell cultures by methods including, but not limited to, ammonium sulfate or ethanol precipitation, acid extraction, anion or cation exchange chromatography, phosphocellulose chromatography, hydrophobic interaction chromatography, affinity chromatography, hydroxylapatite chromatography, and lectin chromatography. High-performance liquid chromatography (HPLC) can be employed for final purification steps.

Exendins

Exendin-4, a 39-amino acid polypeptide, is a naturally occurring peptide isolated from the salivary secretions of the Gila monster. Animal testing of exendin-4 has shown that its ability to lower blood glucose persists for several hours. Exendin-4, as it occurs in the salivary secretions of the Gila monster, is an amidated peptide. However, it should be understood that the term "exendin," and "exendin-4" specifically refers to both the amidated form of the peptide and the acid form of the peptide.

Certain exendin sequences are compared to the sequence of GLP-1 in Table 1.

TABLE 1

a. H A E G T F T S D V S S Y L E G Q A A K E F I A W L V K G R (NH_2)
b. H S D G T F T S D L S K Q M E E E A V R L F I E W L K N G G P S S G A P P P S (NH_2)
c. D L S K Q M E E E A V R L F I E W L K N G G P S S G A P P P S (NH_2)
d. H G E G T F T S D L S K Q M E E E A V R L F I E W L K N G G P S S G A P P P S (NH_2)
e. H S D A T F T A E Y S K L L A K L A L Q K Y L E S I L G S S T S P R P P S S
f. H S D A T F T A E Y S K L L A K L A L Q K Y L E S I L G S S T S P R P P S
g. H S D A I F T E E Y S K L L A K L A L Q K Y L A S I L G S R T S P P P (NH_2)
h. H S D A I F T Q Q Y S K L L A K L A L Q K Y L A S I L G S R T S P P P (NH_2)

a = GLP-1(7-36) (NH_2) [SEQ. ID NO: 4].
b = exendin 3 (NH_2) [SEQ. ID NO: 7].
c = exendin 4 (9-39)(NH_2) [SEQ. ID NO: 8].
d = exendin 4 (NH_2) [SEQ. ID NO: 9].
e = helospectin I [SEQ. ID NO: 10].
f = helospectin II [SEQ. ID NO: 11].
g = helodermin (NH_2) [SEQ. ID NO: 12].
h = Q^8, Q^9 helodermin (NH_2) [SEQ. ID NO: 13].

As described herein, the nonclinical pharmacology of exendin-4 has been studied. In the brain, exendin-4 binds principally to the *area postrema* and *nucleus tractus solitarius* region in the hindbrain and to the subfornical organ in the forebrain. Exendin-4 binding has been observed in the rat and mouse brain and kidney. The structures to which exendin-4 binds in the kidney are unknown.

Various experiments have compared the biologic actions of exendin-4 and GLP-1 and demonstrated a more favorable spectrum of properties for exendin-4. A single subcutaneous dose of exendin-4 lowered plasma glucose in *db/db* (diabetic) and *ob/ob* (diabetic obese) mice by up to 40%. In Diabetic Fatty Zucker (ZDF) rats, 5 weeks of treatment with exendin-4 lowered HbA_{1c} (a measure of glycosylated hemoglobin used to evaluate plasma glucose levels) by up to 41%. Insulin sensitivity was also improved by 76% following 5 weeks of treatment in obese ZDF rats. In glucose intolerant primates, dose-dependent decreases in plasma glucose were also observed.

An insulinotropic action of exendin-4 has also been observed in rodents, improving insulin response to glucose by over 100% in non-fasted Harlan Sprague Dawley (HSD) rats, and by up to ~10-fold in non-fasted *db/db* mice. Higher pretreatment plasma glucose concentrations were associated with greater glucose-lowering effects. Thus the observed glucose lowering

effect of exendin-4 appears to be glucose-dependent, and minimal if animals are already euglycemic.

Exendin-4 dose dependently slowed gastric emptying in HSD rats and was ~90-fold more potent than GLP-1 for this action. Exendin-4 has also been shown to reduce food intake in NIH/Sw (Swiss) mice following peripheral administration, and was at least 1000 times more potent than GLP-1 for this action. Exendin-4 reduced plasma glucagon concentrations by approximately 40% in anesthetized ZDF rats during hyperinsulinemic, hyperglycemic clamp conditions, but did not affect plasma glucagon concentrations during euglycemic conditions in normal rats. Exendin-4 has been shown to dose-dependently reduce body weight in obese ZDF rats, while in lean ZDF rats, the observed decrease in body weight appears to be transient.

The toxicology of exendin-4 has been investigated in single-dose studies in mice, rats and monkeys, repeated-dose (up to 28 consecutive daily doses) studies in rats and monkeys and *in vitro* tests for mutagenicity and chromosomal alterations. To date, no deaths have occurred, and there have been no observed treatment-related changes in hematology, clinical chemistry, or gross or microscopic tissue changes. Exendin-4 was demonstrated to be non-mutagenic, and did not cause chromosomal aberrations at the concentrations tested (up to 5000 μg/mL).

In support of the investigation of the nonclinical pharmacokinetics and metabolism of exendin-4, a number of immunoassays have been developed. A radioimmunoassay with limited sensitivity (~100 pM) was used in initial pharmacokinetic studies. A two-site IRMA assay for exendin-4 was subsequently validated with a lower limit of quantitation of 15 pM. The bioavailability of exendin-4, given subcutaneously, was found to be approximately 50-80% using the radioimmunoassay. This was similar to that seen following intraperitoneal administration (48-60%). Peak plasma concentrations (C_{max}) occurred between 30 and 43 minutes (T_{max}). Both C_{max} and AUC values were monotonically related to dose. The apparent terminal half-life for exendin-4 given subcutaneously was approximately 90-110 minutes. This was significantly longer than the 14-41 minutes seen following intravenous dosing. Similar results were obtained using the IRMA assay. Degradation studies with exendin-4 compared to GLP-1 indicate that exendin-4 is relatively resistant to degradation.

As used in this specification, the term "exendin agonist" includes any molecules, whether they be peptides, peptide mimetics, or other chemical compounds, that bind to or activate a receptor or receptors at which exendin exerts its affect on PCOS, such as the GLP-1(7-36)amide

receptor, and its second messenger cascade. For example, exendin agonists include molecules having insulinotropic activity and that are agonists of (*i.e.*, activate) the GLP-1 receptor molecule and its second messenger activity on, *inter alia*, insulin producing β-cells.

The structure activity relationship (SAR) of exendin was investigated for structures that may relate to the activity of exendin, for its stability to metabolism, and for improvement of its physical characteristics, especially as it pertains to peptide stability and to amenability to alternative delivery systems, and various exendin agonist peptide compounds have been invented. Exendin agonists include exendin analogs with agonist activity in which one or more naturally occurring amino acids are inserted, eliminated or replaced with another amino acid(s). Preferred exendin analogs are peptide analogs of exendin-4.

Exendin analogs include peptides that are encoded by polynucleotides that express biologically active exendin analogs with agonist activity, as defined herein. For instance, exendin analogs may be peptides containing one or more amino acid substitutions, additions or deletions, compared with exendin-4. In one embodiment, the number of substitutions, deletions, or additions is 30 amino acids or less, 25 amino acids or less, 20 amino acids or less, 15 amino acids or less, 10 amino acids or less, 5 amino acids or less or any integer in between these amounts. In one aspect of the invention, the substitutions include one or more conservative substitutions. A "conservative" substitution denotes the replacement of an amino acid residue by another, biologically active similar residue. Examples of conservative substitutions include the substitution of one hydrophobic residue, such as isoleucine, valine, leucine, or methionine for another, or the substitution of one polar residue for another, such as the substitution of arginine for lysine, glutamic for aspartic acids, or glutamine for asparagine, and the like. The following table lists illustrative, but non-limiting, conservative amino acid substitutions.

ORIGINAL RESIDUE	EXEMPLARY SUBSTITUTIONS
ALA	SER, THR
ARG	LYS
ASN	HIS, SER
ASP	GLU, ASN
CYS	SER
GLN	ASN, HIS
GLU	ASP, GLU
GLY	ALA, SER
HIS	ASN, GLN
ILE	LEU, VAL, THR
LEU	ILE, VAL
LYS	ARG, GLN, GLU, THR
MET	LEU, ILE, VAL
PHE	LEU, TYR
SER	THR, ALA, ASN
THR	SER, ALA
TRP	ARG, SER
TYR	PHE
VAL	ILE, LEU, ALA
PRO	ALA

It is further understood that exendin analogs include the above described peptides which have been chemically derivatized or altered, for example, peptides with non-natural amino acid residues (*e.g.*, taurine, β- and γ-amino acid residues and D-amino acid residues), C-terminal functional group modifications, such as amides, esters, and C-terminal ketone modifications and N-terminal functional group modifications, such as acylated amines, Schiff bases, or cyclization, as found, for example, in the amino acid pyroglutamic acid.

Also included in the present invention are peptide sequences having greater than 50% sequence identity, and preferably greater than 90% sequence identity to (1) SEQ ID NOS: 7 and 9; and (2) to truncated sequences thereof. As used herein, sequence identity refers to a comparison made between two molecules using standard algorithms well known in the art. The preferred algorithm for calculating sequence identity for the present invention is the Smith-Waterman algorithm, where SEQ ID NO: 9 [*i.e.*, exendin-4] is used as the reference sequence to define the percentage identity of homologs over its length. The choice of parameter values for matches, mismatches, and insertions or deletions is arbitrary, although some parameter values have been found to yield more biologically realistic results than others. One preferred set of parameter values for the Smith-Waterman algorithm is set forth in the "maximum similarity

segments" approach, which uses values of 1 for a matched residue and -⅓ for a mismatched residue (a residue being either a single nucleotide or single amino acid). Waterman, *Bull. Math. Biol.* 46; 473 (1984). Insertions and deletions (indels), x, are weighted as $x_k = 1 + ⅓k$, where k is the number of residues in a given insert or deletion. *Id.*

Novel exendin analogs with agonist activity are described in commonly owned PCT Application Serial No. PCT/US98/16387 filed August 6, 1998, entitled "Novel Exendin Agonist Compounds," which claims the benefit of U.S. Patent Application Serial No. 60/055,404, filed August 8, 1997, both of which are herein incorporated by reference.

Other novel exendin analogs with agonist activity are described in commonly owned PCT Application Serial No. PCT/US98/24210, filed November 13, 1998, entitled "Novel Exendin Agonist Compounds," which claims the benefit of U.S. Provisional Application No. 60/065,442 filed November 14, 1997, both of which are herein incorporated by reference.

Still other novel exendin analogs with agonist activity are described in commonly owned PCT Application Serial No. PCT/US98/24273, filed November 13, 1998, entitled "Novel Exendin Agonist Compounds," which claims the benefit of U.S. Provisional Application No. 60/066,029 filed November 14, 1997, both of which are herein incorporated by reference.

Still other exendin analogs with agonist activity are described in commonly owned PCT Application Serial No. PCT/US97/14199, filed August 8, 1997, entitled "Methods for Regulating Gastrointestinal Activity," which is a continuation-in-part of U.S. Patent Application Serial No. 08/694,954 filed August 8, 1996, both of which are hereby incorporated by reference.

Still other exendin analogs with agonist activity are described in commonly owned PCT Application Serial No. PCT/US98/00449, filed January 7, 1998, entitled "Use of Exendins and Agonists Thereof for the Reduction of Food Intake," which claims priority to U.S. Provisional Application No. 60/034,90 filed January 7, 1997, both of which are hereby incorporated by reference.

Still other exendin analogs with agonist activity are described in commonly owned PCT Application Serial No. PCT/US01/00719, filed January 9, 2001, entitled "Use of Exendins and Agonists Thereof for Modulation of Triglyceride Levels and Treatment of Dyslipidemia," which claims priority to U.S. Provisional Application No. 60/175,365 filed January 10, 2000, both of which are hereby incorporated by reference.

Still other exendin analogs with agonist activity are described in commonly owned PCT Application Serial No. PCT/US00/00902, filed January 14, 2000, entitled "Novel Exendin Agonist Formulations and Methods of Administration Thereof," which claims priority to U.S. Provisional Application No. 60/116,380 filed January 14, 1999, both of which are hereby incorporated by reference.

Still other exendin analogs with agonist activity are described in commonly owned PCT Application Serial No. PCT/US03/16699, filed May 28, 2003, entitled "Novel Exendin Agonist Formulations and Methods of Administration Thereof," which claims priority to U.S. Application No. 10/157,224 filed May 28, 2002, both of which are hereby incorporated by reference.

Still other exendin analogs with agonist activity are described in commonly owned PCT Application Serial No. PCT/US00/00942, filed January 14, 2000, entitled "Methods of Glucagon Suppression," which claims priority to U.S. Provisional Application No. 60/132,017 filed April 30, 1999, both of which are hereby incorporated by reference.

Still other exendin analogs with agonist activity are described in commonly owned PCT Application Serial No. PCT/US00/14231, filed May 23, 2000, entitled "Use of Exendins and Agonists Thereof for the Treatment of Gestational Diabetes Mellitus," which claims priority to U.S. Application No. 09/323,867 filed June 1, 1999, both of which are hereby incorporated by reference.

Still other exendin analogs with agonist activity are described in commonly owned PCT Application Serial No. PCT/US99/02554, filed February 5, 1999, entitled "Inotropic and Diuretic Effects of Exendin and GLP-1," which claims priority to U.S. Provisional Application No. 60/075,122 filed February 13, 1998, both of which are hereby incorporated by reference.

Activity as exendin agonists and exendin analogs with agonist activity can be indicated, for example, by activity in the assays described below. Effects of exendins or exendin agonists on PCOS can be identified, evaluated, or screened for, using the methods described herein, or other art-known or equivalent methods for determining effect on PCOS. Negative receptor assays or screens for exendin agonist compounds or candidate exendin agonist compounds, such as a GLP-1 receptor assay/screen described above, an amylin receptor assay/screen using an amylin receptor preparation as described in U.S. Patent No. 5,264,372, issued November 23, 1993, the contents of which are incorporated herein by reference, one or more calcitonin receptor

assays/screens using, for example, T47D and MCF7 breast carcinoma cells, which contain calcium receptors coupled to the stimulation of adenyl cyclase activity, and/or a CGRP receptor assay/screen using, for example, SK-N-MC cells.

Certain preferred exendin analogs with agonist activity include:

exendin-4 (1-30) [SEQ ID NO 14: His Gly Glu Gly Thr Phe Thr Ser Asp Leu Ser Lys Gln Met Glu Glu Glu Ala Val Arg Leu Phe Ile Glu Trp Leu Lys Asn Gly Gly];

exendin-4 (1-30) amide [SEQ ID NO 15: His Gly Glu Gly Thr Phe Thr Ser Asp Leu Ser Lys Gln Met Glu Glu Glu Ala Val Arg Leu Phe Ile Glu Trp Leu Lys Asn Gly Gly-NH_2];

exendin-4 (1-28) amide [SEQ ID NO 16: His Gly Glu Gly Thr Phe Thr Ser Asp Leu Ser Lys Gln Met Glu Glu Glu Ala Val Arg Leu Phe Ile Glu Trp Leu Lys Asn-NH_2];

^{14}Leu,^{25}Phe exendin-4 amide [SEQ ID NO 17: His Gly Glu Gly Thr Phe Thr Ser Asp Leu Ser Lys Gln Leu Glu Glu Glu Ala Val Arg Leu Phe Ile Glu Phe Leu Lys Asn Gly Gly Pro Ser Ser Gly Ala Pro Pro Pro Ser-NH_2];

^{14}Leu,^{25}Phe exendin-4 (1-28) amide [SEQ ID NO 18: His Gly Glu Gly Thr Phe Thr Ser Asp Leu Ser Lys Gln Leu Glu Glu Glu Ala Val Arg Leu Phe Ile Glu Phe Leu Lys Asn-NH_2]; and

^{14}Leu,^{22}Ala,^{25}Phe exendin-4 (1-28) amide [SEQ ID NO 19: His Gly Glu Gly Thr Phe Thr Ser Asp Leu Ser Lys Gln Leu Glu Glu Glu Ala Val Arg Leu Ala Ile Glu Phe Leu Lys Asn-NH_2].

Also included within the scope of the present invention are pharmaceutically acceptable salts of the compounds of formula (I-VIII) and pharmaceutical compositions including said compounds and salts thereof.

FORMULA I

Exendin analogs with agonist activity also include those described in U.S. Provisional Application No. 60/065,442, including compounds of the formula (I) [SEQ ID NO. 20]:

Xaa_1 Xaa_2 Xaa_3 Gly Xaa_5 Xaa_6 Xaa_7 Xaa_8 Xaa_9 Xaa_{10}
Xaa_{11} Xaa_{12} Xaa_{13} Xaa_{14} Xaa_{15} Xaa_{16} Xaa_{17} Ala Xaa_{19} Xaa_{20}
Xaa_{21} Xaa_{22} Xaa_{23} Xaa_{24} Xaa_{25} Xaa_{26} Xaa_{27} Xaa_{28}-Z_1;

wherein

Xaa_1 is His, Arg or Tyr;

Xaa_2 is Ser, Gly, Ala or Thr;

Xaa_3 is Asp or Glu;

Xaa_5 is Ala or Thr;

Xaa_6 is Ala, Phe, Tyr or naphthylalanine;

Xaa_7 is Thr or Ser;

Xaa_8 is Ala, Ser or Thr;

Xaa_9 is Asp or Glu;

Xaa_{10} is Ala, Leu, Ile, Val, pentylglycine or Met;

Xaa_{11} is Ala or Ser;

Xaa_{12} is Ala or Lys;

Xaa_{13} is Ala or Gln;

Xaa_{14} is Ala, Leu, Ile, pentylglycine, Val or Met;

Xaa_{15} is Ala or Glu;

Xaa_{16} is Ala or Glu;

Xaa_{17} is Ala or Glu;

Xaa_{19} is Ala or Val;

Xaa_{20} is Ala or Arg;

Xaa_{21} is Ala or Leu;

Xaa_{22} is Ala, Phe, Tyr or naphthylalanine;

Xaa_{23} is Ile, Val, Leu, pentylglycine, tert-butylglycine or Met;

Xaa_{24} is Ala, Glu or Asp;

Xaa_{25} is Ala, Trp, Phe, Tyr or naphthylalanine;

Xaa_{26} is Ala or Leu;

Xaa_{27} is Ala or Lys;

Xaa_{28} is Ala or Asn;

Z_1 is-OH,

$-NH_2$

Gly-Z_2,

Gly Gly-Z_2,

Gly Gly Xaa_{31}-Z_2,

Gly Gly Xaa_{31} Ser-Z_2,

Gly Gly Xaa_{31} Ser Ser-Z_2,

Gly Gly Xaa_{31} Ser Ser Gly-Z_2,

Gly Gly Xaa_{31} Ser Ser Gly Ala-Z_2,

Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36}-Z_2,

Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36} Xaa_{37}-Z_2 or

Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36} Xaa_{37} Xaa_{38}-Z_2;

Xaa_{31}, Xaa_{36}, Xaa_{37} and Xaa_{38} are independently Pro,homoproline, 3Hyp, 4Hyp, thioproline, N-alkylglycine, N-alkylpentylglycine or N-alkylalanine; and

Z_2 is -OH or -NH_2;

provided that no more than three of Xaa_3, Xaa_5, Xaa_6, Xaa_8, Xaa_{10}, Xaa_{11}, Xaa_{12}, Xaa_{13}, Xaa_{14}, Xaa_{15}, Xaa_{16}, Xaa_{17}, Xaa_{19}, Xaa_{20}, Xaa_{21}, Xaa_{24}, Xaa_{25}, Xaa_{26}, Xaa_{27} and Xaa_{28} are Ala.

Preferred N-alkyl groups for N-alkylglycine, N-alkylpentylglycine and N-alkylalanine include lower alkyl groups preferably of 1 to about 6 carbon atoms, more preferably of 1 to 4 carbon atoms.

Preferred exendin analogs include those wherein Xaa_1 is His or Tyr. More preferably Xaa_1 is His.

Preferred are those compounds wherein Xaa_2 is Gly.

Preferred are those compounds wherein Xaa_{14} is Leu, pentylglycine or Met.

Preferred compounds are those wherein Xaa_{25} is Trp or Phe.

Preferred compounds are those where Xaa_6 is Phe or naphthylalanine; Xaa_{22} is Phe or naphthylalanine and

Xaa_{23} is Ile or Val.

Preferred are compounds wherein Xaa_{31}, Xaa_{36}, Xaa_{37} and Xaa_{38} are independently selected from Pro, homoproline, thioproline and N-alkylalanine.

Preferably Z_1 is -NH_2.

Preferably Z_2 is -NH_2.

According to one aspect, preferred are compounds of formula (I) wherein Xaa_1 is His or Tyr, more preferably His; Xaa_2 is Gly; Xaa_6 is Phe or naphthylalanine; Xaa_{14} is Leu, pentylglycine or Met; Xaa_{22} is Phe or naphthylalanine; Xaa_{23} is Ile or Val; Xaa_{31}, Xaa_{36}, Xaa_{37} and Xaa_{38} are independently selected from Pro, homoproline, thioproline or N-alkylalanine. More preferably Z_1 is -NH_2.

According to an especially preferred aspect, especially preferred compounds include those of formula (I) wherein: Xaa_1 is His or Arg; Xaa_2 is Gly or Ala; Xaa_3 is Asp or Glu; Xaa_5 is Ala or Thr; Xaa_6 is Ala, Phe or nephthylalaine; Xaa_7 is Thr or Ser; Xaa_8 is Ala, Ser or Thr; Xaa_9 is Asp or Glu; Xaa_{10} is Ala, Leu or pentylglycine; Xaa_{11} is Ala or Ser; Xaa_{12} is Ala or Lys; Xaa_{13} is Ala or Gln; Xaa_{14} is Ala, Leu or pentylglycine; Xaa_{15} is Ala or Glu; Xaa_{16} is Ala or Glu; Xaa_{17} is Ala or Glu; Xaa_{19} is Ala or Val; Xaa_{20} is Ala or Arg; Xaa_{21} is Ala or Leu; Xaa_{22} is Phe or naphthylalanine; Xaa_{23} is Ile, Val or tert-butylglycine; Xaa_{24} is Ala, Glu or Asp; Xaa_{25} is Ala, Trp or Phe; Xaa_{26} is Ala or Leu; Xaa_{27} is Ala or Lys; Xaa_{28} is Ala or Asn; Z_1 is -OH, $-NH_2$, Gly-Z_2, Gly Gly-Z_2, Gly Gly Xaa_{31}-Z_2, Gly Gly Xaa_{31} Ser-Z_2, Gly Gly Xaa_{31} Ser Ser-Z_2, Gly Gly Xaa_{31} Ser Ser Gly-Z_2, Gly Gly Xaa_{31} Ser Ser Gly Ala-Z_2, Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36}-Z_2, Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36} Xaa_{37}-Z_2, Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36} Xaa_{37} Xaa_{38}-Z_2; Xaa_{31}, Xaa_{36}, Xaa_{37} and Xaa_{38} being independently Pro homoproline, thioproline or N-methylalanine; and Z_2 being -OH or $-NH_2$; provided that no more than three of Xaa_3, Xaa_5, Xaa_6, Xaa_8, Xaa_{10}, Xaa_{11}, Xaa_{12}, Xaa_{13}, Xaa_{14}, Xaa_{15}, Xaa_{16}, Xaa_{17}, Xaa_{19}, Xaa_{20}, Xaa_{21}, Xaa_{24}, Xaa_{25}, Xaa_{26}, Xaa_{27} and Xaa_{28} are Ala. Especially preferred compounds include those set forth in PCT application Serial No. PCT/US98/24210, filed November 13, 1998, entitled "Novel Exendin Agonist Compounds" identified therein as compounds 2-23.

According to an especially preferred aspect, provided are compounds where Xaa_{14} is Leu, Ile, Val or pentylglycine, more preferably Leu or pentylglycine, and Xaa_{25} is Phe, Tyr or naphthylalanine, more preferably Phe or naphthylalanine. These compounds will be less susceptive to oxidative degration, both in vitro and in vivo, as well as during synthesis of the compound.

FORMULA II

Exendin analogs with agonist activity also include those described in U.S. Provisional Application No. 60/066,029, including compounds of the formula (II)[SEQ ID NO. 21]:

$Xaa_1\ Xaa_2\ Xaa_3\ Xaa_4\ Xaa_5\ Xaa_6\ Xaa_7\ Xaa_8\ Xaa_9\ Xaa_{10}$
$Xaa_{11}\ Xaa_{12}\ Xaa_{13}\ Xaa_{14}\ Xaa_{15}\ Xaa_{16}\ Xaa_{17}$ Ala $Xaa_{19}\ Xaa_{20}$
$Xaa_{21}\ Xaa_{22}\ Xaa_{23}\ Xaa_{24}\ Xaa_{25}\ Xaa_{26}\ Xaa_{27}\ Xaa_{28}$-$Z_1$;

wherein:

Xaa_1 is His, Arg, Tyr, Ala, Norval, Val or Norleu;

Xaa_2 is Ser, Gly, Ala or Thr;

Xaa_3 is Ala, Asp or Glu;

Xaa_4 is Ala, Norval, Val, Norleu or Gly;

Xaa_5 is Ala or Thr;

Xaa_6 is Phe, Tyr or naphthylalanine;

Xaa_7 is Thr or Ser;

Xaa_8 is Ala, Ser or Thr;

Xaa_9 is Ala, Norval, Val, Norleu, Asp or Glu;

Xaa_{10} is Ala, Leu, Ile, Val, pentylglycine or Met;

Xaa_{11} is Ala or Ser;

Xaa_{12} is Ala or Lys;

Xaa_{13} is Ala or Gln;

Xaa_{14} is Ala, Leu, Ile, pentylglycine, Val or Met;

Xaa_{15} is Ala or Glu;

Xaa_{16} is Ala or Glu;

Xaa_{17} is Ala or Glu;

Xaa_{19} is Ala or Val;

Xaa_{20} is Ala or Arg;

Xaa_{21} is Ala or Leu;

Xaa_{22} is Phe, Tyr or naphthylalanine;

Xaa_{23} is Ile, Val, Leu, pentylglycine, tert-butylglycine or Met;

Xaa_{24} is Ala, Glu or Asp;

Xaa_{25} is Ala, Trp, Phe, Tyr or naphthylalanine;

Xaa_{26} is Ala or Leu;

Xaa_{27} is Ala or Lys;

Xaa_{28} is Ala or Asn;

Z_1 is -OH,

$-NH_2$,

Gly-Z_2,

Gly Gly-Z_2,

Gly Gly Xaa_{31}-Z_2,

Gly Gly Xaa_{31} Ser-Z_2,

Gly Gly Xaa_{31} Ser Ser-Z_2,

Gly Gly Xaa_{31} Ser Ser Gly-Z_2,

Gly Gly Xaa_{31} Ser Ser Gly Ala-Z_2,

Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36}-Z_2,

Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36} Xaa_{37}-Z_2,

Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36} Xaa_{37} Xaa_{38}-Z_2 or

Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36} Xaa_{37} Xaa_{38} Xaa_{39}-Z_2;

Xaa_{31}, Xaa_{36}, Xaa_{37} and Xaa_{38} are independently Pro,homoproline, 3Hyp, 4Hyp, thioproline, N-alkylglycine, N-alkylpentylglycine or N-alkylalanine; and

Z_2 is -OH or -NH_2;

provided that no more than three of Xaa_3, Xaa_4, Xaa_5, Xaa_6, Xaa_8, Xaa_9, Xaa_{10}, Xaa_{11}, Xaa_{12}, Xaa_{13}, Xaa_{14}, Xaa_{15}, Xaa_{16}, Xaa_{17}, Xaa_{19}, Xaa_{20}, Xaa_{21}, Xaa_{24}, Xaa_{25}, Xaa_{26}, Xaa_{27} and Xaa_{28} are Ala; and provided also that, if Xaa_1 is His, Arg or Tyr, then at least one of Xaa_3, Xaa_4 and Xaa_9 is Ala.

Preferred N-alkyl groups for N-alkylglycine, N-alkylpentylglycine and N-alkylalanine include lower alkyl groups preferably of 1 to about 6 carbon atoms, more preferably of 1 to 4 carbon atoms. Suitable compounds of formula (II) include those described in application Serial No. PCT/US98/24273, filed November 13, 1998, entitled "Novel Exendin Agonist Compounds", identified therein in Examples 1-89 ("Compounds 1-89," respectively), as well as those corresponding compounds identified therein in Examples 104 and 105.

Preferred such exendin analogs include those wherein Xaa_1 is His, Ala or Norval. More preferably Xaa_1 is His or Ala. Most preferably Xaa_1 is His.

Preferred are those compounds of formula (II) wherein Xaa_2 is Gly.

Preferred are those compounds of formula (II) wherein Xaa_3 is Ala.

Preferred are those compounds of formula (II) wherein Xaa_4 is Ala.

Preferred are those compounds of formula (II) wherein Xaa_9 is Ala.

Preferred are those compounds of formula (II) wherein Xaa_{14} is Leu, pentylglycine or Met.

Preferred compounds of formula (II) are those wherein Xaa_{25} is Trp or Phe.

Preferred compounds of formula (II) are those where Xaa_6 is Ala, Phe or naphthylalanine; Xaa_{22} is Phe or naphthylalanine; and Xaa_{23} is Ile or Val.

Preferred are compounds of formula (II) wherein Xaa_{31}, Xaa_{36}, Xaa_{37} and Xaa_{38} are independently selected from Pro, homoproline, thioproline and N-alkylalanine.

Preferably Z_1 is $-NH_2$.

Preferably Z_2 is $-NH_2$.

According to one aspect, preferred are compounds of formula (II) wherein Xaa_1 is Ala, His or Tyr, more preferably Ala or His; Xaa_2 is Ala or Gly; Xaa_6 is Phe or naphthylalanine; Xaa_{14} is Ala, Leu, pentylglycine or Met; Xaa_{22} is Phe or naphthylalanine; Xaa_{23} is Ile or Val; Xaa_{31}, Xaa_{36}, Xaa_{37} and Xaa_{38} are independently selected from Pro, homoproline, thioproline or N-alkylalanine; and Xaa_{39} is Ser or Tyr, more preferably Ser. More preferably Z_1 is $-NH_2$.

According to an especially preferred aspect, especially preferred compounds include those of formula (II) wherein: Xaa_1 is His or Ala; Xaa_2 is Gly or Ala; Xaa_3 is Ala, Asp or Glu; Xaa_4 is Ala or Gly; Xaa_5 is Ala or Thr; Xaa_6 is Phe or naphthylalanine; Xaa_7 is Thr or Ser; Xaa_8 is Ala, Ser or Thr; Xaa_9 is Ala, Asp or Glu; Xaa_{10} is Ala, Leu or pentylglycine; Xaa_{11} is Ala or Ser; Xaa_{12} is Ala or Lys; Xaa_{13} is Ala or Gln; Xaa_{14} is Ala, Leu, Met or pentylglycine; Xaa_{15} is Ala or Glu; Xaa_{16} is Ala or Glu; Xaa_{17} is Ala or Glu; Xaa_{19} is Ala or Val; Xaa_{20} is Ala or Arg; Xaa_{21} is Ala or Leu; Xaa_{22} is Phe or naphthylalanine; Xaa_{23} is Ile, Val or tert-butylglycine; Xaa_{24} is Ala, Glu or Asp; Xaa_{25} is Ala, Trp or Phe; Xaa_{26} is Ala or Leu; Xaa_{27} is Ala or Lys; Xaa_{28} is Ala or Asn; Z_1 is -OH, $-NH_2$, Gly-Z_2, Gly Gly-Z_2, Gly Gly Xaa_{31}-Z_2, Gly Gly Xaa_{31} Ser-Z_2, Gly Gly Xaa_{31} Ser Ser-Z_2, Gly Gly Xaa_{31} Ser Ser Gly-Z_2, Gly Gly Xaa_{31} Ser Ser Gly Ala-Z_2, Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36}-Z_2, Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36} Xaa_{37}-Z_2, Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36} Xaa_{37} Xaa_{38}-Z_2 or Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36} Xaa_{37} Xaa_{38} Xaa_{39}-Z_2; Xaa_{31}, Xaa_{36}, Xaa_{37} and Xaa_{38} being independently Pro homoproline, thioproline or N-methylalanine; and Z_2 being -OH or $-NH_2$; provided that no more than three of Xaa_3, Xaa_5, Xaa_6, Xaa_8, Xaa_{10}, Xaa_{11}, Xaa_{12}, Xaa_{13}, Xaa_{14}, Xaa_{15}, Xaa_{16}, Xaa_{17}, Xaa_{19}, Xaa_{20}, Xaa_{21}, Xaa_{24}, Xaa_{25}, Xaa_{26}, Xaa_{27} and Xaa_{28} are Ala; and provided also that, if Xaa_1 is His, Arg or Tyr, then at least one of Xaa_3, Xaa_4 and Xaa_9 is Ala. Especially preferred compounds of formula (II) include those described in application Serial No. PCT/US98/24273, filed November 13, 1998, entitled "Novel Exendin Agonist Compounds" as having the amino acid sequence of SEQ. ID. NOS. 5-93 therein.

According to an especially preferred aspect, provided are compounds of formula (II) where Xaa_{14} is Ala, Leu, Ile, Val or pentylglycine, more preferably Leu or pentylglycine, and Xaa_{25} is Ala, Phe, Tyr or naphthylalanine, more preferably Phe or naphthylalanine. These compounds will be less susceptible to oxidative degration, both in vitro and in vivo, as well as during synthesis of the compound.

FORMULA III

Also within the scope of the present invention are narrower genera of compounds having peptides of various lengths, for example genera of compounds which do not include peptides having a length of 28, 29 or 30 amino acid residues, respectively. Additionally, the present invention includes narrower genera of compounds described in PCT application Serial No. PCT/US98/24210, filed November 13, 1998, entitled "Novel Exendin Agonist Compounds" and having particular amino acid sequences, for example, compounds of the formula (III) [SEQ. ID. NO. 22]:

$Xaa_1\ Xaa_2\ Xaa_3\ Gly\ Xaa_5\ Xaa_6\ Xaa_7\ Xaa_8\ Xaa_9\ Xaa_{10}$
$Xaa_{11}\ Xaa_{12}\ Xaa_{13}\ Xaa_{14}\ Xaa_{15}\ Xaa_{16}\ Xaa_{17}\ Ala\ Xaa_{19}$
$Xaa_{20}\ Xaa_{21}\ Xaa_{22}\ Xaa_{23}\ Xaa_{24}\ Xaa_{25}\ Xaa_{26}\ Xaa_{27}\ Xaa_{28}\text{-}Z_1$;

wherein:

Xaa_1 is His or Arg;
Xaa_2 is Gly or Ala;
Xaa_3 is Asp or Glu;
Xaa_5 is Ala or Thr;
Xaa_6 is Ala, Phe or naphthylalanine;
Xaa_7 is Thr or Ser;
Xaa_8 is Ala, Ser or Thr;
Xaa_9 is Asp or Glu;
Xaa_{10} is Ala, Leu or pentylglycine;
Xaa_{11} is Ala or Ser;
Xaa_{12} is Ala or Lys;
Xaa_{13} is Ala or Gln;

Xaa_{14} is Ala, Leu or pentylglycine;

Xaa_{15} is Ala or Glu;

Xaa_{16} is Ala or Glu;

Xaa_{17} is Ala or Glu;

Xaa_{19} is Ala or Val;

Xaa_{20} is Ala or Arg;

Xaa_{21} is Ala or Leu;

Xaa_{22} is Phe or naphthylalanine;

Xaa_{23} is Ile, Val or tert-butylglycine;

Xaa_{24} is Ala, Glu or Asp;

Xaa_{25} is Ala, Trp, or Phe;

Xaa_{26} is Ala or Leu;

Xaa_{27} is Ala or Lys;

Xaa_{28} is Ala or Asn;

Z_1 is -OH,

$-NH_2$,

Gly-Z_2,

Gly Gly -Z_2,

Gly Gly Xaa_{31}-Z_2,

Gly Gly Xaa_{31} Ser-Z_2,

Gly Gly Xaa_{31} Ser Ser-Z_2,

Gly Gly Xaa_{31} Ser Ser Gly-Z_2,

Gly Gly Xaa_{31} Ser Ser Gly Ala-Z_2,

Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36}-Z_2,

Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36} Xaa_{37}-Z_2 or

Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36} Xaa_{37} Xaa_{38}-Z_2;

Xaa_{31}, Xaa_{36}, Xaa_{37} and Xaa_{38} are independently selected from the group consisting of Pro, homoproline, thioproline and N-methylylalanine; and

Z_2 is -OH or $-NH_2$;

provided that no more than three of Xaa_3, Xaa_5, Xaa_6, Xaa_8, Xaa_{10}, Xaa_{11}, Xaa_{12}, Xaa_{13}, Xaa_{14}, Xaa_{15}, Xaa_{16}, Xaa_{17}, Xaa_{19}, Xaa_{20}, Xaa_{21}, Xaa_{24}, Xaa_{25}, Xaa_{26}, Xaa_{27} and Xaa_{28} are Ala; and pharmaceutically acceptable salts thereof.

FORMULA IV

Additionally, the present invention includes narrower genera of peptide compounds described in PCT Application Serial No. PCT/US98/24273, filed November 13, 1998, entitled "Novel Exendin Agonist Compounds" as having particular amino acid sequences, for example, compounds of the formula [IV] [SEQ. ID. NO. 23]:

$Xaa_1\ Xaa_2\ Xaa_3\ Xaa_5\ Xaa_5\ Xaa_6\ Xaa_7\ Xaa_8\ Xaa_9\ Xaa_{10}$
$Xaa_{11}\ Xaa_{12}\ Xaa_{13}\ Xaa_{14}\ Xaa_{15}\ Xaa_{16}\ Xaa_{17}$ Ala Xaa_{19}
$Xaa_{20}\ Xaa_{21}\ Xaa_{22}\ Xaa_{23}\ Xaa_{24}\ Xaa_{25}\ Xaa_{26}\ Xaa_{27}\ Xaa_{28}$-$Z_1$;

wherein:

Xaa_1 is His or Ala;
Xaa_2 is Gly or Ala;
Xaa_3 is Ala, Asp or Glu;
Xaa_4 is Ala or Gly;
Xaa_5 is Ala or Thr;
Xaa_6 is Phe or naphthylalanine;
Xaa_7 is Thr or Ser;
Xaa_8 is Ala, Ser or Thr;
Xaa_9 is Ala, Asp or Glu;
Xaa_{10} is Ala, Leu or pentylglycine;
Xaa_{11} is Ala or Ser;
Xaa_{12} is Ala or Lys;
Xaa_{13} is Ala or Gln;
Xaa_{14} is Ala, Leu, Met or pentylglycine;
Xaa_{15} is Ala or Glu;
Xaa_{16} is Ala or Glu;
Xaa_{17} is Ala or Glu;

Xaa_{19} is Ala or Val;

Xaa_{20} is Ala or Arg;

Xaa_{21} is Ala or Leu;

Xaa_{22} is Phe or naphthylalanine;

Xaa_{23} is Ile, Val or tert-butylglycine;

Xaa_{24} is Ala, Glu or Asp;

Xaa_{25} is Ala, Trp or Phe;

Xaa_{26} is Ala or Leu;

Xaa_{27} is Ala or Lys;

Xaa_{28} is Ala or Asn;

Z_1 is -OH,

$-NH_2$,

Gly-Z_2,

Gly Gly-Z_2

Gly Gly Xaa_{31}-Z_2,

Gly Gly Xaa_{31} Ser-Z_2,

Gly Gly Xaa_{31} Ser Ser-Z_2,

Gly Gly Xaa_{31} Ser Ser Gly-Z_2,

Gly Gly Xaa_{31} Ser Ser Gly Ala-Z_2,

Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36}-Z_2,

Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36} Xaa_{37}-Z_2

Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36} Xaa_{37} Xaa_{38}-Z_2

Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36} Xaa_{37} Xaa_{38} Ser-Z_2;

Xaa_{31}, Xaa_{36}, Xaa_{37} and Xaa_{38} are independently Pro,homoproline, thioproline, or N-methylylalanine; and

Z_2 is -OH or $-NH_2$;

provided that no more than three of Xaa_3, Xaa_5, Xaa_6, Xaa_8, Xaa_{10}, Xaa_{11}, Xaa_{12}, Xaa_{13}, Xaa_{14}, Xaa_{15}, Xaa_{16}, Xaa_{17}, Xaa_{19}, Xaa_{20}, Xaa_{21}, Xaa_{24}, Xaa_{25}, Xaa_{26}, Xaa_{27}, and Xaa_{28} are Ala; and provided that, if Xaa_1 is His, Arg or Tyr, then at least one of Xaa_3, Xaa_4 and Xaa_9 is Ala; and pharmaceutically acceptable salts thereof.

Preferred compounds of formula (IV) include those wherein Xaa_1 is His, Ala, Norval or 4-imidazopropionyl. Preferably, Xaa_1 is His, or 4-imidazopropionyl or Ala, more preferably His or 4-imidazopropionyl.

Preferred compounds of formula (IV) include those wherein Xaa2 is Gly.

Preferred compounds of formula (IV) include those wherein Xaa4 is Ala.

Preferred compounds of formula (IV) include those wherein Xaa9 is Ala.

Preferred compounds of formula (IV) include those wherein Xaa14 is Leu, pentylglycine or Met.

Preferred compounds of formula (IV) include those wherein Xaa25 is Trp or Phe.

Preferred compounds of formula (IV) include those wherein Xaa6 is Ala, Phe or naphthylalanine; Xaa22 is Phe or naphthylalanine; and Xaa23 is Ile or Val.

Preferred compounds of formula (IV) include those wherein Z1 is -NH2.

Preferred compounds of formula (IV) include those wherein Xaa31, Xaa36, Xaa37 and Xaa38 are independently selected from the group consisting of Pro, homoproline, thioproline and N-alkylalanine.

Preferred compounds of formula (IV) include those wherein Xaa39 is Ser or Tyr, preferably Ser.

Preferred compounds of formula (IV) include those wherein Z2 is -NH2.

Preferred compounds of formula (IV) include those 42 wherein Z1 is -NH2.

Preferred compounds of formula (IV) include those wherein Xaa21 is Lys-NH□-R where R is Lys, Arg, C1-C10 straight chain or branched alkanoyl.

Preferred compounds of formula (IV) include those wherein X1 is Lys Asn, Lys-NHε-R Asn, or Lys-NHε-R Ala where R is Lys, Arg, C1-C10 straight chain or branched alkanoyl. Preferred compounds of formula (IV) include those having an amino acid sequence described in PCT application Serial No. PCT/US98/24273, filed November 13, 1998, entitled "Novel Exendin Agonist Compounds" as being selected from SEQ. ID. NOS. 95-110 therein.

FORMULA V

Also provided are compounds described in PCT application PCT/US98/24210, filed November 13, 1998, entitled "Novel Exendin Agonist Compounds", including compounds of the formula (V) [SEQ. ID. NO. 24]:

Xaa_1 Xaa_2 Xaa_3 Gly Xaa_5 Xaa_6 Xaa_7 Xaa_8 Xaa_9 Xaa_{10}

Xaa_{11} Xaa_{12} Xaa_{13} Xaa_{14} Xaa_{15} Xaa_{16} Xaa_{17} Ala Xaa_{19} Xaa_{20}

Xaa_{21} Xaa_{22} Xaa_{23} Xaa_{24} Xaa_{25} Xaa_{26} X_1 -Z_1;

wherein

Xaa_1 is His, Arg or Tyr or 4-imidazopropionyl;

Xaa_2 is Ser, Gly, Ala or Thr;

Xaa_3 is Asp or Glu;

Xaa_5 is Ala or Thr;

Xaa_6 is Ala, Phe, Tyr or naphthylalanine;

Xaa_7 is Thr or Ser;

Xaa_8 is Ala, Ser or Thr;

Xaa_9 is Asp or Glu;

Xaa_{10} is Ala, Leu, Ile, Val, pentylglycine or Met;

Xaa_{11} is Ala or Ser;

Xaa_{12} is Ala or Lys;

Xaa_{13} is Ala or Gln;

Xaa_{14} is Ala, Leu, Ile, pentylglycine, Val or Met;

Xaa_{15} is Ala or Glu;

Xaa_{16} is Ala or Glu;

Xaa_{17} is Ala or Glu;

Xaa_{19} is Ala or Val;

Xaa_{20} is Ala or Arg;

Xaa_{21} is Ala, Leu or Lys-NH^{ε}-R where R is Lys, Arg, C_1-C_{10} straight chain or branched alkanoyl or cycloalkylalkanoyl;

Xaa_{22} is Phe, Tyr or naphthylalanine;

Xaa_{23} is Ile, Val, Leu, pentylglycine, tert-butylglycine or Met;

Xaa_{24} is Ala, Glu or Asp;

Xaa_{25} is Ala, Trp, Phe, Tyr or naphthylalanine;

Xaa_{26} is Ala or Leu;

X_1 is Lys Asn, Asn Lys, Lys-NH^{ε}-R Asn, Asn Lys-NH^{ε}-R, Lys-NH^{ε}-R Ala, Ala Lys-NH^{ε}-R where R is Lys, Arg, C_1-C_{10} straight chain or branched alkanoyl or cycloalkylalkanoyl

Z_1 is -OH,

-NH_2,

Gly-Z_2,

Gly Gly-Z_2,

Gly Gly Xaa_{31}-Z_2,

Gly Gly Xaa_{31} Ser-Z_2,

Gly Gly Xaa_{31} Ser Ser-Z_2,

Gly Gly Xaa_{31} Ser Ser Gly-Z_2,

Gly Gly Xaa_{31} Ser Ser Gly Ala-Z_2,

Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36}-Z_2,

Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36} Xaa_{37}-Z_2 or

Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36} Xaa_{37} Xaa_{38}-Z_2;

Xaa_{31}, Xaa_{36}, Xaa_{37} and Xaa_{38} are independently selected from the group consisting of Pro, homoproline, 3Hyp, 4Hyp, thioproline, N-alkylglycine, N-alkylpentylglycine and N-alkylalanine; and

Z_2 is -OH or -NH_2;

provided that no more than three of Xaa_3, Xaa_5, Xaa_6, Xaa_8, Xaa_{10}, Xaa_{11}, Xaa_{12}, Xaa_{13}, Xaa_{14}, Xaa_{15}, Xaa_{16}, Xaa_{17}, Xaa_{19}, Xaa_{20}, Xaa_{21}, Xaa_{24}, Xaa_{25}, and Xaa_{26} are Ala. Also within the scope of the present invention are pharmaceutically acceptable salts of the compound of formula (V) and pharmaceutical compositions including said compounds and salts thereof.

Preferred exendin analogs of formula (V) include those wherein Xaa_1 is His, Tyr or 4-imidazopropionyl. More preferably Xaa_1 is His.

Preferred are those compounds of formula (V) wherein Xaa_1 is 4-imidazopropionyl.

Preferred are those compounds of formula (V) wherein Xaa_2 is Gly.

Preferred compounds of formula (V) are those wherein Xaa_{14} is Leu, pentylglycine or Met.

Preferred compounds of formula (V) are those wherein Xaa_{25} is Trp or Phe.

According to one aspect, preferred are compounds of formula (V) wherein Xaa_6 is Phe or naphthylalanine; and Xaa_{22} is Phe or naphthylalanine; and Xaa_{23} is Ile or Val. More preferably,

Z_1 is $-NH_2$. According to one aspect, especially preferred are such compounds of formula (V) wherein Xaa_{31}, Xaa_{36}, Xaa_{37} and Xaa_{38} are independently selected from the group consisting of Pro, homoproline, thioproline and N-alkylalanine. More preferds, Z_2 is $-NH_2$.

Preferred compounds of formula (V) include those wherein X_1 is Lys Asn, Lys-NH^{ε}-R Asn, or Lys-NH^{ε}-R Ala where R is Lys, Arg, C_1-C_{10} straight chain or branched alkanoyl. Preferred compounds of formula (V) include compounds described in PCT application Serial No. PCT/US98/24210, filed November 13, 1998, entitled "Novel Exendin Agonist Compounds" and identified therein as Compound Nos. 62-69.

Preferred such exendin analogs include those wherein Xaa_1 is His, Ala or Norval. More preferably Xaa_1 is His or Ala. Most preferably Xaa_1 is His.

Preferred are those compounds of formula (V) wherein Xaa_2 is Gly.

Preferred are those compounds of formula (V) wherein Xaa_3 is Ala.

Preferred are those compounds of formula (V) wherein Xaa_4 is Ala.

Preferred are those compounds of formula (V) wherein Xaa_9 is Ala.

Preferred are those compounds of formula (V) wherein Xaa_{14} is Leu, pentylglycine or Met.

Preferred compounds of formula (V) are those wherein Xaa_{25} is Trp or Phe.

Preferred compounds of formula (V) are those where Xaa_6 is Ala, Phe or naphthylalanine; Xaa_{22} is Phe or naphthylalanine; and Xaa_{23} is Ile or Val.

Preferred are compounds of formula (V) wherein Xaa_{31}, Xaa_{36}, Xaa_{37} and Xaa_{38} are independently selected from Pro, homoproline, thioproline and N-alkylalanine.

Preferably Z_1 is $-NH_2$.

Preferably Z_2 is $-NH_2$.

According to one aspect, preferred are compounds of formula (V) wherein Xaa_1 is Ala, His or Tyr, more preferably Ala or His; Xaa_2 is Ala or Gly; Xaa_6 is Phe or naphthylalanine; Xaa_{14} is Ala, Leu, pentylglycine or Met; Xaa_{22} is Phe or naphthylalanine; Xaa_{23} is Ile or Val; Xaa_{31}, Xaa_{36}, Xaa_{37} and Xaa_{38} are independently selected from Pro, homoproline, thioproline or N-alkylalanine; and Xaa_{39} is Ser or Tyr, more preferably Ser. More preferably Z_1 is $-NH_2$.

According to an especially preferred aspect, especially preferred compounds include those of formula (V) wherein: Xaa_1 is His or Ala; Xaa_2 is Gly or Ala; Xaa_3 is Ala, Asp or Glu; Xaa_4 is Ala or Gly; Xaa_5 is Ala or Thr; Xaa_6 is Phe or naphthylalanine; Xaa_7 is Thr or Ser; Xaa_8

is Ala, Ser or Thr; Xaa_9 is Ala, Asp or Glu; Xaa_{10} is Ala, Leu or pentylglycine; Xaa_{11} is Ala or Ser; Xaa_{12} is Ala or Lys; Xaa_{13} is Ala or Gln; Xaa_{14} is Ala, Leu, Met or pentylglycine; Xaa_{15} is Ala or Glu; Xaa_{16} is Ala or Glu; Xaa_{17} is Ala or Glu; Xaa_{19} is Ala or Val; Xaa_{20} is Ala or Arg; Xaa_{21} is Ala or Leu; Xaa_{22} is Phe or naphthylalanine; Xaa_{23} is Ile, Val or tert-butylglycine; Xaa_{24} is Ala, Glu or Asp; Xaa_{25} is Ala, Trp or Phe; Xaa_{26} is Ala or Leu; Xaa_{27} is Ala or Lys; Xaa_{28} is Ala or Asn; Z_1 is -OH, $-NH_2$, Gly-Z_2, Gly Gly-Z_2, Gly Gly Xaa_{31}-Z_2, Gly Gly Xaa_{31} Ser-Z_2, Gly Gly Xaa_{31} Ser Ser-Z_2, Gly Gly Xaa_{31} Ser Ser Gly-Z_2, Gly Gly Xaa_{31} Ser Ser Gly Ala-Z_2, Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36}-Z_2, Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36} Xaa_{37}-Z_2, Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36} Xaa_{37} Xaa_{38}-Z_2 or Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36} Xaa_{37} Xaa_{38} Xaa_{39}-Z_2; Xaa_{31}, Xaa_{36}, Xaa_{37} and Xaa_{38} being independently Pro homoproline, thioproline or N-methylalanine; and Z_2 being -OH or $-NH_2$; provided that no more than three of Xaa_3, Xaa_5, Xaa_6, Xaa_8, Xaa_{10}, Xaa_{11}, Xaa_{12}, Xaa_{13}, Xaa_{14}, Xaa_{15}, Xaa_{16}, Xaa_{17}, Xaa_{19}, Xaa_{20}, Xaa_{21}, Xaa_{24}, Xaa_{25}, Xaa_{26}, Xaa_{27} and Xaa_{28} are Ala; and provided also that, if Xaa_1 is His, Arg or Tyr, then at least one of Xaa_3, Xaa_4 and Xaa_9 is Ala. Especially preferred compounds of formula (V) include those described in PCT application Serial No. PCT/US98/24210, filed November 13, 1998, entitled "Novel Exendin Agonist Compounds" and having the amino acid sequences identified therein as SEQ. ID. NOS. 5-93.

According to an especially preferred aspect, provided are compounds of formula (V) where Xaa14 is Ala, Leu, Ile, Val or pentylglycine, more preferably Leu or pentylglycine, and Xaa25 is Ala, Phe, Tyr or naphthylalanine, more preferably Phe or naphthylalanine. These compounds will be less susceptible to oxidative degration, both in vitro and in vivo, as well as during synthesis of the compound.

FORMULA VI

Also provided are peptide compounds described in PCT Application Serial No. PCT/US98/24273, filed November 13, 1998, entitled "Novel Exendin Agonist Compounds", including compounds of the formula (VI) [SEQ. ID. NO. 25]:

Xaa_1 Xaa_2 Xaa_3 Xaa_4 Xaa_5 Xaa_6 Xaa_7 Xaa_8 Xaa_9 Xaa_{10}
Xaa_{11} Xaa_{12} Xaa_{13} Xaa_{14} Xaa_{15} Xaa_{16} Xaa_{17} Ala Xaa_{19} Xaa_{20}
Xaa_{21} Xaa_{22} Xaa_{23} Xaa_{24} Xaa_{25} Xaa_{26} X_1-Z_1;

wherein

Xaa_1 is His, Arg, Tyr, Ala, Norval, Val, Norleu or 4-imidazopropionyl;

Xaa_2 is Ser, Gly, Ala or Thr;

Xaa_3 is Ala, Asp or Glu;

Xaa_4 is Ala, Norval, Val, Norleu or Gly;

Xaa_5 is Ala or Thr;

Xaa_6 is Phe, Tyr or naphthylalanine;

Xaa_7 is Thr or Ser;

Xaa_8 is Ala, Ser or Thr;

Xaa_9 is Ala, Norval, Val, Norleu, Asp or Glu;

Xaa_{10} is Ala, Leu, Ile, Val, pentylglycine or Met;

Xaa_{11} is Ala or Ser;

Xaa_{12} is Ala or Lys;

Xaa_{13} is Ala or Gln;

Xaa_{14} is Ala, Leu, Ile, pentylglycine, Val or Met;

Xaa_{15} is Ala or Glu;

Xaa_{16} is Ala or Glu;

Xaa_{17} is Ala or Glu;

Xaa_{19} is Ala or Val;

Xaa_{20} is Ala or Arg;

Xaa_{21} is Ala, Leu or Lys-NH^{ε}-R where R is Lys, Arg, C^{1-10} straight chain or branched alkanoyl or cycloalleyl-alkanoyl;

Xaa_{22} is Phe, Tyr or naphthylalanine;

Xaa_{23} is Ile, Val, Leu, pentylglycine, tert-butylglycine or Met;

Xaa_{24} is Ala, Glu or Asp;

Xaa_{25} is Ala, Trp, Phe, Tyr or naphthylalanine;

Xaa_{26} is Ala or Leu;

X_1 is Lys Asn, Asn Lys, Lys-NH^{ε}-R Asn, Asn Lys-NH^{ε}-R, Lys-NH^{ε}-R Ala, Ala Lys-NH^{ε}-R where R is Lys, Arg, C_1-C_{10} straight chain or branched alkanoyl or cycloalkylalkanoyl

Z_1 is -OH,

$-NH_2$,

Gly-Z_2,

Gly Gly-Z_2,

Gly Gly Xaa_{31}-Z_2,

Gly Gly Xaa_{31} Ser-Z_2,

Gly Gly Xaa_{31} Ser Ser-Z_2,

Gly Gly Xaa_{31} Ser Ser Gly-Z_2,

Gly Gly Xaa_{31} Ser Ser Gly Ala-Z_2,

Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36}-Z_2,

Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36} Xaa_{37}-Z_2,

Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36} Xaa_{37} Xaa_{38}-Z_2 or

Gly Gly Xaa_{31} Ser Ser Gly Ala Xaa_{36} Xaa_{37} Xaa_{38} Xaa_{39}-Z_2;

Xaa_{31}, Xaa_{36}, Xaa_{37} and Xaa_{38} are independently selected from the group consisting of Pro, homoproline, 3Hyp, 4Hyp, thioproline, N-alkylglycine, N-alkylpentylglycine and N-alkylalanine; and

Z_2 is -OH or -NH_2;

provided that no more than three of Xaa_3, Xaa_4, Xaa_5, Xaa_6, Xaa_8, Xaa_9, Xaa_{10}, Xaa_{11}, Xaa_{12}, Xaa_{13}, Xaa_{14}, Xaa_{15}, Xaa_{16}, Xaa_{17}, Xaa_{19}, Xaa_{20}, Xaa_{21}, Xaa_{24}, Xaa_{25}, Xaa_{26}, are Ala; and provided also that, if Xaa_1 is His, Arg, Tyr, or 4-imidazopropionyl then at least one of Xaa_3, Xaa_4 and Xaa_9 is Ala.

Preferred compounds of formula (VI) include those wherein Xaa_1 is His, Ala, Norval or 4-imidazopropionyl. Preferably, Xaa_1 is His, or 4-imidazopropionyl or Ala, more preferably His or 4-imidazopropionyl.

Preferred compounds of formula (VI) include those wherein Xaa_2 is Gly.

Preferred compounds of formula (VI) include those wherein Xaa_4 is Ala.

Preferred compounds of formula (VI) include those wherein Xaa_9 is Ala.

Preferred compounds of formula (VI) include those wherein Xaa_{14} is Leu, pentylglycine or Met.

Preferred compounds of formula (VI) include those wherein Xaa_{25} is Trp or Phe.

Preferred compounds of formula (VI) include those wherein Xaa_6 is Ala, Phe or naphthylalanine; Xaa_{22} is Phe or naphthylalanine; and Xaa_{23} is Ile or Val.

Preferred compounds of formula (VI) include those wherein Z_1 is -NH_2.

Preferred compounds of formula (VI) include those wherein Xaa_{31}, Xaa_{36}, Xaa_{37} and Xaa_{38} are independently selected from the group consisting of Pro, homoproline, thioproline and N-alkylalanine.

Preferred compounds of formula (VI) include those wherein Xaa_{39} is Ser or Tyr, preferably Ser.

Preferred compounds of formula (VI) include those wherein Z_2 is $-NH_2$.

Preferred compounds of formula (VI) include those 42 wherein Z_1 is $-NH_2$.

Preferred compounds of formula (VI) include those wherein Xaa_{21} is Lys-NH^{ε}-R where R is Lys, Arg, C_1-C_{10} straight chain or branched alkanoyl.

Preferred compounds of formula (VI) include those wherein X_1 is Lys Asn, Lys-NH^{ε}-R Asn, or Lys-NH^{ε}-R Ala where R is Lys, Arg, C_1-C_{10} straight chain or branched alkanoyl.

Preferred compounds of formula (VI) include those described in PCT Application Serial No. PCT/US98/24273, filed November 13, 1998, entitled "Novel Exendin Agonist Compounds" as having an amino acid sequence selected from those identified therein as SEQ. ID. NOS. 95-110.

FORMULA VII

Compounds particularly useful according to the present invention are exendin analogs with agonist activity described in U.S. Patent Application Serial No. 09/003,869, filed January 7, 1998, entitled "Use of Exendins And Agonists Thereof For The Reduction of Food Intake", including compounds of the formula (VII) [SEQ. ID. NO. 26]:

Xaa_1 Xaa_2 Xaa_3 Gly Thr Xaa_4 Xaa_5 Xaa_6 Xaa_7 Xaa_8
Ser Lys Gln Xaa_9 Glu Glu Glu Ala Val Arg Leu
Xaa_{10} Xaa_{11} Xaa_{12} Xaa_{13} Leu Lys Asn Gly Gly Xaa_{14}
Ser Ser Gly Ala Xaa_{15} Xaa_{16} Xaa_{17} Xaa_{18}-Z

wherein:

Xaa_1 is His, Arg or Tyr;

Xaa_2 is Ser, Gly, Ala or Thr;

Xaa_3 is Asp or Glu;

Xaa_4 is Phe, Tyr or naphthalanine;

Xaa_5 is Thr or Ser;

Xaa_6 is Ser or Thr;

Xaa_7 is Asp or Glu;

Xaa_8 is Leu, Ile, Val, pentylglycine or Met;

Xaa_9 is Leu, Ile, pentylglycine, Val or Met;

Xaa_{10} is Phe, Tyr or naphthalanine;

Xaa_{11} is Ile, Val, Leu, pentylglycine, tert-butylglycine or Met;

Xaa_{12} is Glu or Asp; Xaa_{13} is Trp, Phe, Tyr, or naphthylalanine;

Xaa_{14}, Xaa_{15}, Xaa_{16} and Xaa_{17} are independently Pro, homoproline, 3Hyp, 4Hyp, thioproline, N-alkylglycine, N-alkylpentylglycine or N-alkylalanine;

Xaa_{18} is Ser, Thr or Tyr; and Z is -OH or $-NH_2$;

with the proviso that the compound does not have the formula of either SEQ. ID. NOS. 7 or 9. Preferred N-alkyl groups for N-alkylglycine, N-alkylpentylglycine and N-alkylalanine include lower alkyl groups preferably of 1 to about 6 carbon atoms, more preferably of 1 to 4 carbon atoms. Also useful in the present invention are pharmaceutically acceptable salts of the compounds of formula (VII).

Preferred exendin analogs include those wherein Xaa_1 is His or Tyr. More preferably Xaa_1 is His.

Preferred are those compounds wherein Xaa_2 is Gly.

Preferred are those compounds wherein Xaa_9 is Leu, pentylglycine or Met.

Preferred compounds include those wherein Xaa_{13} is Trp or Phe.

Also preferred are compounds where Xaa_4 is Phe or naphthalanine; Xaa_{11} is Ile or Val and Xaa_{14}, Xaa_{15}, Xaa_{16} and Xaa_{17} are independently selected from Pro, homoproline, thioproline or N-alkylalanine. Preferably N-alkylalanine has a N-alkyl group of 1 to about 6 carbon atoms.

According to an especially preferred aspect, Xaa_{15}, Xaa_{16} and Xaa_{17} are the same amino acid reside.

Preferred are compounds wherein Xaa_{18} is Ser or Tyr, more preferably Ser.

Preferably Z is $-NH_2$.

According to one aspect, preferred are compounds of formula (VII) wherein Xaa_1 is His or Tyr, more preferably His; Xaa_2 is Gly; Xaa_4 is Phe or naphthalanine; Xaa_9 is Leu,

pentylglycine or Met; Xaa_{10} is Phe or naphthalanine; Xaa_{11} is Ile or Val; Xaa_{14}, Xaa_{15}, Xaa_{16} and Xaa_{17} are independently selected from Pro, homoproline, thioproline or N-alkylalanine; and Xaa_{18} is Ser or Tyr, more preferably Ser. More preferably Z is $-NH_2$.

According to an especially preferred aspect, especially preferred compounds include those of formula (VII) wherein: Xaa_1 is His or Arg; Xaa_2 is Gly; Xaa_3 is Asp or Glu; Xaa_4 is Phe or napthylalanine; Xaa_5 is Thr or Ser; Xaa_6 is Ser or Thr; Xaa_7 is Asp or Glu; Xaa_8 is Leu or pentylglycine; Xaa_9 is Leu or pentylglycine; Xaa_{10} is Phe or naphthylalanine; Xaa_{11} is Ile, Val or t-butyltylglycine; Xaa_{12} is Glu or Asp; Xaa_{13} is Trp or Phe; Xaa_{14}, Xaa_{15}, Xaa_{16}, and Xaa_{17} are independently Pro, homoproline, thioproline, or N-methylalanine; Xaa_{18} is Ser or Tyr: and Z is -OH or $-NH_2$; with the proviso that the compound does not have the formula of either SEQ. ID. NOS. 7 or 9. More preferably Z is $-NH_2$..

According to an especially preferred aspect, provided are compounds where Xaa_9 is Leu, Ile, Val or pentylglycine, more preferably Leu or pentylglycine, and Xaa_{13} is Phe, Tyr or naphthylalanine, more preferably Phe or naphthylalanine. These compounds are believed to exhibit advantageous duration of action and to be less subject to oxidative degration, both in vitro and in vivo, as well as during synthesis of the compound.

FORMULA VIII

Also provided are compounds described in PCT Application Serial No. PCT/US98/16387, filed August 6, 1998, entitled "Novel Exendin Agonist Compounds", including compounds of the formula (VIII) [SEQ. ID. NO. 27]:

Xaa_1 Xaa_2 Xaa_3 Gly Thr Xaa_4 Xaa_5 Xaa_6 Xaa_7 Xaa_8
Ser Lys Gln Xaa_9 Glu Glu Glu Ala Val Arg Leu
Xaa_{10} Xaa_{11} Xaa_{12} Xaa_{13} Leu X_1 Gly Gly Xaa_{14}
Ser Ser Gly Ala Xaa_{15} Xaa_{16} Xaa_{17} Xaa_{18}-Z

wherein:

Xaa_1 is His, Arg, Tyr or 4-imidazopropionyl;

Xaa_2 is Ser, Gly, Ala or Thr;

Xaa_3 is Asp or Glu;

Xaa_4 is Phe, Tyr or naphthylalanine;

Xaa_5 is Thr or Ser;

Xaa_6 is Ser or Thr;

Xaa_7 is Asp or Glu;

Xaa_8 is Leu, Ile, Val, pentylglycine or Met;

Xaa_9 is Leu, Ile, pentylglycine, Val or Met;

Xaa_{10} is Phe, Tyr or naphthylalanine;

Xaa_{11} is Ile, Val, Leu, pentylglycine, tert-butylglycine or Met;

Xaa_{12} is Glu or Asp;

Xaa_{13} is Trp, Phe, Tyr, or naphthylalanine; X_1 is Lys Asn, Asn Lys, Lys-NH^{ε}-R Asn, Asn Lys-NH^{ε}-R where R is Lys, Arg, C_1-C_{10} straight chain or branched alkanoyl or cycloalkylalkanoyl;

Xaa_{14}, Xaa_{15}, Xaa_{16} and Xaa_{17} are independently Pro, homoproline, 3Hyp, 4Hyp, thioproline, N-alkylglycine, N-alkylpentylglycine or N-alkylalanine;

Xaa_{18} is Ser, Thr or Tyr; and Z is -OH or -NH_2;

with the proviso that the compound does not have the formula of either SEQ. ID. NOS. 7 or 9. Suitable compounds of formula (VIII) include compounds described in PCT Application Serial No. PCT/US98/16387, filed August 6, 1998, entitled "Novel Exendin Agonist Compounds" having the amino acid sequences of SEQ. ID. NOS. 37-40 therein.

Preferred exendin analogs of formula (VIII) include those wherein Xaa_1 is His, Tyr or 4-imidazopropionyl. More preferably, Xaa_1 is His or 4-imidazopropionyl.

Preferred are those compounds of formula (VIII) wherein Xaa_2 is Gly.

Preferred are those compounds of formula (VIII) wherein Xaa_9 is Leu, pentylglycine or Met.

Preferred are those compounds of formula (VIII) wherein Xaa_{13} is Trp or Phe.

Preferred are those compounds of formula (VIII) wherein

X_1 is Lys Asn, or Lys-NH^{ε}-R Asn, where R is Lys, Arg, C_1-C_{10} straight chain or branched alkanoyl.

Also preferred are compounds of formula (VIII) wherein Xaa_4 is Phe or naphthylalanine; Xaa_{10} is Phe or naphthylalanine; Xaa_{11} is Ile or Val and Xaa_{14}, Xaa_{15}, Xaa_{16} and Xaa_{17} are independently selected from Pro, homoproline, thioproline or N-alkylalanine. According to an

especially preferred aspect, Xaa_{18} is Ser or Tyr. Preferred are those such compounds wherein Xaa_{18} is Ser.. Preferably, Z is $-NH_2$.

According to one preferred aspect, preferred are compounds of formula (VIII) wherein Xaa_4 is Phe or naphthylalanine; Xaa_{10} is Phe or naphthylalanine; Xaa_{11} is Ile or Val, X_1 is Lys Asn, or Lys-NH^{ε}-R Asn, where R is Lys, Arg, C_1-C_{10} straight chain or branched alkanoyl and Xaa_{14}, Xaa_{15}, Xaa_{16} and Xaa_{17} are independently selected from Pro, homoproline, thioproline or N-alkylalanine.

In another embodiment, exendins and exendin analogs of the invention do not include the peptides of SEQ ID NOS. 7-13. In this embodiment, preferred exendin analogs include the analogs of Formulas (I-VIII), with the proviso that the analogs do not include the peptides of SEQ ID NOs: 7-13.

Exendins and exendin agonists that are peptides, such as exendin analogs, described herein may be prepared through peptide purification as described in, for example, Eng, *et al.*, *J. Biol. Chem.* 265:20259-62, 1990; and Eng, *et al.*, *J. Biol. Chem.* 267:7402-05, 1992, hereby incorporated by reference herein. Alternatively, exendins and exendin agonists that are peptides may be prepared by methods known to those skilled in the art, for example, as described in Raufman, *et al.*, *J. Biol. Chem.* 267:21432-37, 1992), hereby incorporated by reference herein, using standard solid-phase peptide synthesis techniques and preferably an automated or semiautomated peptide synthesizer. The compounds that constitute active ingredients of the formulations and dosages of the present invention may be prepared using standard solid-phase peptide synthesis techniques and preferably an automated or semiautomated peptide synthesizer. Typically, using such techniques, an α-N-carbamoyl protected amino acid and an amino acid attached to the growing peptide chain on a resin are coupled at room temperature in an inert solvent such as dimethylformamide, N-methylpyrrolidinone or methylene chloride in the presence of coupling agents such as dicyclohexylcarbodiimide and 1-hydroxybenzotriazole in the presence of a base such as diisopropylethylamine. The α-N-carbamoyl protecting group is removed from the resulting peptide-resin using a reagent such as trifluoroacetic acid or piperidine, and the coupling reaction repeated with the next desired N-protected amino acid to be added to the peptide chain. Suitable N-protecting groups are well known in the art, with t-butyloxycarbonyl (tBoc) and fluorenylmethoxycarbonyl (Fmoc) being preferred herein.

The solvents, amino acid derivatives and 4-methylbenzhydryl-amine resin used in the peptide synthesizer may be purchased from Applied Biosystems Inc. (Foster City, CA). The following side-chain protected amino acids may be purchased from Applied Biosystems, Inc.: BSD-112344.1-Arg(Pmc), Boc-Thr(Bzl), Fmoc-Thr(t-Bu), Boc-Ser(Bzl), Fmoc-Ser(t-Bu), Boc-Tyr(BrZ), Fmoc-Tyr(t-Bu), Boc-Lys(Cl-Z), Fmoc-Lys(Boc), Boc-Glu(Bzl), Fmoc-Glu(t-Bu), Fmoc-His(Trt), Fmoc-Asn(Trt), and Fmoc-Gln(Trt). Boc-His(BOM) may be purchased from Applied Biosystems, Inc. or Bachem Inc. (Torrance, CA). Anisole, dimethylsulfide, phenol, ethanedithiol, and thioanisole may be obtained from Aldrich Chemical Company (Milwaukee, WI). Air Products and Chemicals (Allentown, PA) supplies HF. Ethyl ether, acetic acid and methanol may be purchased from Fisher Scientific (Pittsburgh, PA).

Solid phase peptide synthesis may be carried out with an automatic peptide synthesizer (Model 430A, Applied Biosystems Inc., Foster City, CA) using the NMP/HOBt (Option 1) system and tBoc or Fmoc chemistry (see, Applied Biosystems User's Manual for the ABI 430A Peptide Synthesizer, Version 1.3B July 1, 1988, section 6, pp. 49-70, Applied Biosystems, Inc., Foster City, CA) with capping. Boc-peptide-resins may be cleaved with HF (-50°C to 0°C, 1 hour). The peptide may be extracted from the resin with alternating water and acetic acid, and the filtrates lyophilized. The Fmoc-peptide resins may be cleaved according to standard methods (Introduction to Cleavage Techniques, Applied Biosystems, Inc., 1990, pp. 6-12). Peptides may also be assembled using an Advanced Chem Tech Synthesizer (Model MPS 350, Louisville, Kentucky).

Peptides may be purified by RP-HPLC (preparative and analytical) using a Waters Delta Prep 3000 system. A C4, C8 or C18 preparative column (10 μ, 2.2 x 25 cm; Vydac, Hesperia, CA) may be used to isolate peptides, and purity may be determined using a C4, C8 or C18 analytical column (5 μ, 0.46 x 25 cm; Vydac). Solvents (A=0.1% TFA/water and B=0.1% TFA/CH_3CN) may be delivered to the analytical column at a flowrate of 1.0 ml/min and to the preparative column at 15 ml/min. Amino acid analyses may be performed on the Waters Pico Tag system and processed using the Maxima program. Peptides may be hydrolyzed by vapor-phase acid hydrolysis (115°C, 20-24 h). Hydrolysates may be derivatized and analyzed by standard methods (Cohen, et al., The Pico Tag Method: A Manual of Advanced Techniques for Amino Acid Analysis, pp. 11-52, Millipore Corporation, Milford, MA (1989)). Fast atom bombardment analysis may be carried out by M-Scan, Incorporated (West Chester, PA). Mass

calibration may be performed using cesium iodide or cesium iodide/glycerol. Plasma desorption ionization analysis using time of flight detection may be carried out on an Applied Biosystems Bio-Ion 20 mass spectrometer. Electrospray mass spectroscopy may be carried and on a VG-Trio machine.

Exendins and exendin agonists that are peptides may also be prepared using recombinant DNA techniques, using methods now known in the art. See, *e.g.*, Sambrook *et al.*, Molecular Cloning: A Laboratory Manual, 2d Ed., Cold Spring Harbor (1989). Alternatively, such compounds may be prepared by homogeneous phase peptide synthesis methods. Non-peptide compounds useful in the present invention may be prepared by art-known methods. For example, phosphate-containing amino acids and peptides containing such amino acids, may be prepared using methods known in the art. See, *e.g.*, Bartlett and Landen, Biorg. Chem. 14:356-377 (1986).

Methods of the invention

The methods and compositions of this invention may be used to treat PCOS. Many of the symptoms associated with PCOS stem from an underlying insulin resistance. The symptoms associated with PCOS include insulin resistance, hyperinsulinemia, hyperandrogenism, type-2 diabetes mellitus, irregular menses, anovulation and infertility. Therefore, the present invention provides methods of treating insulin resistance in a subject suffering from PCOS comprising the step of administering GLP-1.

Insulin resistance may be due to any one or more events including abnormal prereceptor (*e.g.*, abnormal ligand or competition), receptor (*e.g.*, abnormal structure, affinity of ligand to receptor, or number of receptors), or postreceptor (*e.g.*, abnormal signaling) events. Insulin resistance may be determined by a number of methods known in the art. For example, the euglycemic hyperinsulinemic clamp technique may be used to diagnose insulin resistance (Rao, G., *Am. Fam. Physician* (2001) 63:1159-63). This technique involves intravenous administration of an insulin dose while simultaneously maintaining glucose at a pre-set level within the normal range by also administering glucose. At equilibrium, the amount of glucose uptake by a particular tissue in the presence of a certain dose of insulin can be calculated. Other methods used to detect insulin resistance include the insulin suppression test, intravenous glucose tolerance test, and constant infusion of glucose with model assessment (Rao, G., *supra*).

In another embodiment, the invention provides a method of preventing the onset of type-2 diabetes mellitus in a subject suffering from PCOS comprising the step of administering GLP-1, exendin, or agonists or analogs of these compounds. Type-2 diabetes mellitus is often a result of hyperinsulinemia caused by insulin resistance. Thus, treating insulin resistance in these patients would prevent the development of type-2 diabetes mellitus. Methods of diagnosing type-2 diabetes mellitus are well-known in the art.

In yet another embodiment, this invention provides a method of restoring regular menses, restoring regular ovulation and/or restoring fertility in a subject suffering from PCOS comprising the step of administering GLP-1, exendin, or agonists or analogs of these compounds. PCOS patients often exhibit hyperandrogenism, which is thought to be caused by hyperinsulinemia. The hyperandrogenism leads to follicular involution, anovulation and infertility. Thus, reducing insulin resistance by administering GLP-1, exendin, or agonists or analogs of these compounds can ameliorate hyperinsulinemia, thereby restoring regular menses, ovulation, and/or fertility.

In another embodiment, this invention provides a method for treating PCOS comprising coadministering to a patient in need thereof GLP-1, exendin, or agonists or analogs of these compounds with a drug that induces ovulation (*e.g.*, clomiphene, follistim, or Gonal–F).

In yet another embodiment, this invention provides a method for treating PCOS comprising coadministering to a patient in need thereof GLP-1, exendin, or agonists or analogs of these compounds with an anti-androgenic drug, including but not limited to a birth control pill (*e.g.*, progestogens and estrogens), spironolactone, flutamide and finasteride.

In yet another embodiment, this invention provides a method for treating PCOS comprising coadministering to a patient in need thereof GLP-1, exendin, or agonists or analogs of these compounds with an insulin-sensitizing agent, including, but not limited to, metformin, D-Chiro-inositol, diazoxide, and PPAR inhibitors (*e.g.*, troglitazone (Rezulin), rosiglitazone (Avandia) and pioglitazone (Actos)).

In another embodiment, this invention provides a method for treating PCOS comprising coadministering to a patient in need thereof GLP-1, exendin, or agonists or analogs of these compounds with glucose. In a more preferred embodiment the glucose is administered intravenously.

When the compounds of this invention are administered in combination therapies as described above, they may be administered sequentially or concurrently to the patient.

Alternatively, the pharmaceutical compositions of this invention may be comprised of a combination of a GLP-1, exendin, or agonists or analogs of these compounds molecule and another agent as described above.

In a preferred embodiment, the subject suffering from PCOS is a mammal, *e.g.*, dog, cat, rodent. In a more preferred embodiment, the subject suffering from PCOS is a human.

Pharmaceutical Compositions

GLP-1, exendin, and agonists or analogs of these compounds may be formulated into pharmaceutical compositions for administration to subjects, including humans. These pharmaceutical compositions, preferably include an amount of GLP-1, exendin, or agonists or analogs of these compounds effective to treat, *e.g.*, insulin resistance, prevent the onset of type-2 diabetes mellitus, restore regular menses and/or ovulation and treat infertility in a subject suffering from PCOS, and a pharmaceutically acceptable carrier.

Pharmaceutically acceptable carriers useful in these pharmaceutical compositions include, *e.g.*, ion exchangers, alumina, aluminum stearate, lecithin, serum proteins, such as human serum albumin, buffer substances such as phosphates, glycine, sorbic acid, potassium sorbate, partial glyceride mixtures of saturated vegetable fatty acids, water, salts or electrolytes, such as protamine sulfate, disodium hydrogen phosphate, potassium hydrogen phosphate, sodium chloride, zinc salts, colloidal silica, magnesium trisilicate, polyvinyl pyrrolidone, cellulose-based substances, polyethylene glycol, sodium carboxymethylcellulose, polyacrylates, waxes, polyethylene-polyoxypropylene-block polymers, polyethylene glycol and wool fat.

The compositions of the present invention may be administered parenterally, orally, by inhalation spray, topically, rectally, nasally, buccally, vaginally or via an implanted reservoir. The term "parenteral" as used herein includes subcutaneous, intravenous, intramuscular, intra-articular, intra-synovial, intrasternal, intrathecal, intrahepatic, intralesional and intracranial injection or infusion techniques. Preferably, the compositions are administered by an infusion pump or subcutaneous injection of a slow release formulation

Sterile injectable forms of the compositions of this invention may be aqueous or oleaginous suspension. These suspensions may be formulated according to techniques known in the art, using suitable dispersing or wetting agents and suspending agents. The sterile injectable preparation may also be a sterile injectable solution or suspension in a non-toxic parenterally-acceptable diluent or solvent, for example as a solution in 1,3-butanediol. Among the acceptable

vehicles and solvents that may be employed are water, Ringer's solution and isotonic sodium chloride solution. In addition, sterile, fixed oils are conventionally employed as a solvent or suspending medium. For this purpose, any bland fixed oil may be employed including synthetic mono- or di-glycerides. Fatty acids, such as oleic acid and its glyceride derivatives are useful in the preparation of injectables, as are natural pharmaceutically-acceptable oils, such as olive oil or castor oil, especially in their polyoxyethylated versions. These oil solutions or suspensions may also contain a long-chain alcohol diluent or dispersant, such as carboxymethyl cellulose or similar dispersing agents that are commonly used in the formulation of pharmaceutically acceptable dosage forms, including emulsions and suspensions. Other commonly used surfactants, such as Tweens, Spans and other emulsifying agents or bioavailability enhancers which are commonly used in the manufacture of pharmaceutically acceptable solid, liquid, or other dosage forms may also be used for the purposes of formulation.

Parenteral formulations may be a single bolus dose, an infusion or a loading bolus dose followed with a maintenance dose. These compositions may be administered once a day or on an "as needed" basis.

The pharmaceutical compositions of this invention may be orally administered in any orally acceptable dosage form including, capsules, tablets, aqueous suspensions or solutions. In the case of tablets for oral use, carriers commonly used include lactose and corn starch. Lubricating agents, such as magnesium stearate, are also typically added. For oral administration in a capsule form, useful diluents include lactose and dried cornstarch. When aqueous suspensions are required for oral use, the active ingredient is combined with emulsifying and suspending agents. If desired, certain sweetening, flavoring or coloring agents may also be added.

Alternatively, the pharmaceutical compositions of this invention may be administered in the form of suppositories for rectal administration. These can be prepared by mixing the agent with a suitable non-irritating excipient which is solid at room temperature but liquid at rectal temperature and therefore will melt in the rectum to release the drug. Such materials include cocoa butter, beeswax and polyethylene glycols.

The pharmaceutical compositions of this invention may also be administered topically. Topical application can be effected in a rectal suppository formulation (see above) or in a suitable enema formulation. Topically transdermal patches may also be used.

For topical applications, the pharmaceutical compositions may be formulated in a suitable ointment containing the active component suspended or dissolved in one or more carriers. Carriers for topical administration of the compounds of this invention include, mineral oil, liquid petrolatum, white petrolatum, propylene glycol, polyoxyethylene, polyoxypropylene compound, emulsifying wax and water. Alternatively, the pharmaceutical compositions can be formulated in a suitable lotion or cream containing the active components suspended or dissolved in one or more pharmaceutically acceptable carriers. Suitable carriers include, but are not limited to, mineral oil, sorbitan monostearate, polysorbate 60, cetyl esters wax, cetearyl alcohol, 2-octyldodecanol, benzyl alcohol, and water.

For ophthalmic use, the pharmaceutical compositions may be formulated as micronized suspensions in isotonic, pH-adjusted sterile saline, or, preferably, as solutions in isotonic, pH-adjusted sterile saline, either with or without a preservative such as benzylalkonium chloride. Alternatively, for ophthalmic uses, the pharmaceutical compositions may be formulated in an ointment such as petrolatum.

The pharmaceutical compositions of this invention may also be administered by nasal aerosol or inhalation. Such compositions are prepared according to techniques well-known in the art of pharmaceutical formulation and may be prepared as solutions in saline, employing benzyl alcohol or other suitable preservatives, absorption promoters to enhance bioavailability, fluorocarbons, and/or other conventional solubilizing or dispersing agents.

The amount of GLP-1, exendin, or agonists or analogs of these compounds that may be combined with the carrier materials to produce a single dosage form will vary depending upon the host treated and the particular mode of administration. The compositions can be formulated so that a dosage of between 0.1-1000 pmoles/kg body weight/minute (when administered by infusion) of GLP-1, exendin, or agonists or analogs of these compounds is administered to a patient receiving these compositions. In some embodiments of the invention, the dosage is 1-10 pmoles/kg body weight/minute (when administered by infusion). In a preferred embodiment the dosage is 0.5-2.0 pmoles/kg/min when administered by intravenous infusion. The composition may be administered as a single dose, multiple doses, or over an established period of time in an infusion.

In a preferred embodiment, GLP-1, exendin, or agonists or analogs of these compounds is administered to patients with confirmed polycystic ovary syndrome. In another preferred

embodiment, GLP-1, exendin, or agonists or analogs of these compounds is administered by injection at least once a day or by continuous infusion via pump. In yet another preferred embodiment, GLP-1, exendin, or agonists or analogs of these compounds is formulated for administration from a subcutaneous depot over a period of days to weeks, oral administration or by intermittent inhalation.

A specific dosage and treatment regimen for any particular patient will depend upon a variety of factors, including the particular GLP-1, exendin, or agonists or analogs of these compounds the patient's age, body weight, general health, gender, and diet, and the time of administration, rate of excretion, drug combination, and the severity of the particular disease being treated. Judgment of such factors by medical caregivers is within ordinary skill in the art. The amount of GLP-1, exendin, or agonists or analogs of these compounds will also depend on the individual patient to be treated, the route of administration, the type of formulation, the characteristics of the compound used, the severity of the disease, and the desired effect. The amounts of GLP-1, exendin, or agonists or analogs of these compounds can be determined by pharmacological and pharmacokinetic principles well-known in the art.

In order that the invention described herein may be more fully understood, the following examples are set forth. It should be understood that these examples are for illustrative purposes only and are not to be construed as limiting this invention in any manner.

EXAMPLES

1. Treatment of a PCOS patient with GLP-1

Patients with PCOS are exclusively women. Typically, premenopausal women manifest the disease with complaints of irregular menses, infertility, excessive growth of body hair, acne and loss of scalp hair. Postmenopausal women may have all of these complaints except irregular menses. Obesity, hypertension and diabetes are disorders that commonly accompany PCOS.

The diagnosis of PCOS will be confirmed by measuring the level of serum testosterone and/or the ratio of serum LH/FSH. Elevated levels of serum testosterone (> 60 ng/ml) or an abnormal serum LH/FSH ratio (< 2.5) are indicative of PCOS.

Patients with confirmed PCOS will be treated with GLP-1. GLP-1 will be administered by injection once or more each day or by continuous infusion via pump, which delivers a steady

amount of drug. Alternatively, GLP-1 will be formulated for administration from a subcutaneous depot over days to weeks, by intermittent inhalation or orally.

Irrespective of the mode of administration, the total amount of GLP-1 delivered into the blood of a patient with PCOS will be in the range of 720 to 2880 picomoles/kg/day. This is equivalent to 0.5-2.0 pmoles/kg/min when administered by intravenous infusion.

The efficacy of GLP-1 will be established by determining the amelioration or reversal of the presenting complaint, including but not limited to normalization of menses, restoration of fertility, loss of excess body hair, resolution of acne and cessation of hair loss. Other indicators of GLP-1 efficacy may be used including but not limited to serum testosterone levels and LH/FSH ratios. GLP-1 efficacy will be determined by a decrease in serum testosterone levels and an increase in the LH/FSH ratio.